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GEOLOGICAL ASPECT OF THE LODES OF CORNWALL.[1]

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INTRODUCTION.

Although the west of England mining region of Cornwall and Devonshire has not recently been in a flourishing condition, its past fame entitles it to a claim on the attention of those interested alike in the genesis of tin and copper ores and in the antiquity of mining.

During the last few years a section of the field staff of the Geological Survey of Great Britain has been engaged in remapping the Cornish peninsula and as this work is nearly completed the most recent geological information concerning the region is available. There is quite an extensive literature dealing with the west of England geology and mineralogy, and as this has been acknowledged in the Memoirs of the Geological Survey it will be unnecessary to refer to it here.[2]

HISTORICAL.

ANTIQUITY OF THE MINING IN CORNWALL.

The earliest records of the connection of Cornwall with the

[1] Communicated by permission of the Director of the Geological Survey of England and Wales.

[2] The Geological Survey Memoirs dealing with Cornish Mining are as follows: (1) "Geology of the Lands End District"; (2) "Geology of Camborne and Redruth"; (3) "Geology of Newquay"; (4) "Geology of Plymouth and Liskeard." Other memoirs are in course of preparation.

tin trade are the extracts from the lost writings of Pythias by the Greek historians Strabo and Diodorus Siculus.

Although it is believed that a century before the voyage of Pythias, the Carthaginian Himilco had visited Cornwall with a view to stimulating the tin trade between that country and the continent, there was in the time of Pythias an overland trade between Cornwall and Marseilles—possibly also a sea-borne trade between Cornwall and Cadiz.

When Pythias was in Cornwall he was informed by the inhabitants that the tin, after being cast into ingots, was conveyed to the island of Ictis, which was accessible to foot passengers, at low tide. From here it was taken to the mouth of the river Loire and thence to Marseilles. As to the identity of the island of Ictis there has been considerable discussion in the past, but recently Mr. Clement Reid has shown how the Isle of Wight might have been the Ictis referred to by Pythias,[1] as at that time it is possible that there was a natural causeway between the isle and the mainland which has since been worn away by the scour of the sea. This view is combated by Mr. T. Rice Holmes who, on historical grounds, inclines to the other supposition that the old Ictis and St. Michael's Mount are the same.[2] In either case the antiquity of the tin mining in Cornwall cannot be doubted and with fluctuating activity the production of tin has been continuous to the present time.

The tin mines in the twelfth and thirteenth centuries were under the control of the Kings of England who granted privileges for working them, but for the last 300 years the production of both tin and copper ores has been of national importance.

TOTAL YIELD OF TIN AND COPPER FROM CORNWALL.

An exact estimate of the total metalliferous yield of the county of Cornwall is practically impossible to obtain owing to the absence or uncertainty of the older records. In a brochure by the present writer published in 1907 by the Geological Survey, an estimate of the total known production of the minerals of Corn-

[1] "The Island of Ictis," *Archæologia*, Vol. 59, 1905.
[2] "Ancient Britain and the Invasions of Cæsar," 1907.

wall was made within the limits of a possible error of 10 per cent., as follows:

Total Produce of Metallic Tin from Cornwall.

Between 1201 and 1749 A. D.....711,990 tons
Between 1750 and 1905 A. D.....755,900 tons (from black tin containing 65.02 per cent. of tin).

(Of 283,000 tons of tin yielded between 1201 and 1600 A.D. 75,000 tons were obtained from alluvial deposits, and of 573,800 tons produced between 1601 and 1800 A. D., 473,000 tons were obtained from alluvial deposits.)

Total Produce of Metallic Copper From Cornwall.

Between 1501 and 1725 A. D..... 20,000 tons.
Between 1726 and 1905 A. D.....883,350 tons (from ore containing 7.89 per cent. of metallic copper).

For the amounts of ores yielded from the mines of Cornwall individually the reader is referred to the Memoirs already mentioned.

For over 150 years Cornwall has had formidable rivals in the tin-fields of the East Indies (Bangka and Billiton islands) and while still holding a high place in the world's production of tin ore its output is exceeded by Bolivia, Australia, Siam and Malay —the last country producing about ten times the quantity raised in Cornwall.

In addition to ores of tin and copper Cornwall has yielded considerable amounts of argentiferous-galena, zinc ore and iron pyrites, arsenic, wolfram and of iron ores, ochre and umber. Smaller amounts of bismuth, antimony, nickel ore and uranium have been yielded as by-products or in a small way.

GEOLOGY.

GENERAL GEOLOGICAL DESCRIPTION OF CORNWALL.

With the exception of a few undetermined points the geology of Cornwall has been recently worked out by the Geological Survey. The small key map (Fig. 28) shows the general arrangement of the Palæozoic sedimentary rocks of which the

Fig. 28. Geological map of the Cornwall Region, England.

region is composed together with the igneous masses which were intruded at different periods during the disturbances which have upheaved, folded and cleaved them.

The sedimentary rocks of the western part of the region, south of an east and west line situated north of Truro, are of Lower Palæozoic age as determined by trilobites in the region south of St. Austell, and consist of argillaceous slates of purplish and green color with fine sandstones. The rocks are thoroughly cleaved, folded and overthrust, and contain interbedded quartz lenticles, and in those beds which consist of alternately hard sandy and soft shaly bands there is crush-breccia or pseudo-conglomeratic structure due to the fracturing of the harder bands which under pressure became crushed into lenticular fragments separated by softer argillaceous material. The Lower Palæozoics have been separated into five subdivisions not indicated on the map. These rocks have a strike of E. 30° N. and are supposed to have as a whole an anticlinal arrangement.[1]

The sedimentary rocks of central and east Cornwall are mainly of Devonian age and consist of shales, sandy beds, grits and calcareous bands with an east-and-west strike. The series is much folded and cleaved, the Lower Devonian rocks occurring on the south, and the Middle and Upper on the north. In Watergate Bay, north of Newquay, the sandy and argillaceous Lower Old Red series is seen to occupy the axis of an anticline, the overlying Lower Devonian beds occurring on both the north and south side of that feature. A similar anticlinal structure is discoverable in the Upper Devonian series in the district on the west of Kit Hill in East Cornwall.

The Carboniferous rocks of the region comprise both the Upper and Lower Divisions. The Lower Carboniferous shales and radiolarian cherts, as well as the Upper Devonian shales, are overlain unconformably by the Upper Carboniferous plant-bearing grits and shales.

[1] The discovery of Devonian conglomerates near the Helford river just north of the Lizard serpentine appears to confirm this supposition since, according to Mr. J. B. Hill, they are correlatable with the Devonian shales and sandstones north of Truro.

FIG. 28. Geological map of the Cornwall Region, England.

The igneous rocks of the region comprise the greenstones, lavas and schalsteins, granites, quartz porphyries and mica traps. Under the term greenstone are included a series of pre-granitic basic intrusions comprising diabases, proterobases, porphyrite and epidiorite, most of which have been sheared and more or less altered, particularly near the granite. The lavas are typically represented by spilite—fine-grained rocks belonging, according to Dr. J. S. Flett, to the Essexite group and characterized by exceptional amounts of albite feldspar. The schalsteins occur in patches in both the Upper Devonian and Carboniferous rocks of East Cornwall.

The igneous rocks of Post-Carboniferous age do not as a rule show any foliation or shearing since they were intruded, only at the close of, and as a relief to the great Post-Carboniferous movements to which the folding and cleavage of the Palæozoic sediments are due. The most important of these are the five granite intrusions shown in the figure, together with their fine-grained hypabyssal types, the elvans or quartz-porphyry dykes and the comparatively rare mica traps or minettes.

STRATIGRAPHICAL TABLE.

SEDIMENTARY ROCKS.

Upper? / Middle	Culm grits and shales	Carboniferous	Upper Palæozoic
Lower Culm shales and radiolarian cherts.			
Upper, Middle and Lower Devonian grits, calcareous slates and shales		Devonian	
Lower Old Red shales and fine sandy beds (Dartmouth Beds)			
Gorvan Haven beds		Upper Silurian (Wenlock)	Lower Palæozoic
Veryan slates, sandy beds and quartzites and thin limestones and cherts		Ordovician	
Portscatho slates and sandstones		Cambrian?	
Falmouth slates			
Mylor slates and Dodman (?) Phyllites			

IGNEOUS ROCKS.

Granite	Late or Post-carboniferous
Quartz porphyry (Elvan)	
Mica trap	
Tuffs and lavas	Contemporaneous Carboniferous
Greenstones	

Pillow Lavas and Schalsteins. Greenstones	Upper and Middle Devonian
Pillow Lavas	Older Palæozoic
Greenstone (hypabyssal)	
Gabbro	
Serpentine of the Lizard, with granulite intrusions	

It is with these granite masses that the mineral wealth of the west of England is connected.

The metamorphic rocks include the hornblende and mica schists and quartzites of the Lizard; and the contact-altered rocks in the vicinity of the granite masses.

THE LODES.

The stippled areas on the map indicate the chief tin and copper districts of Cornwall and South Devon. It will be noticed that in all cases the lodes occur concentrated in districts connected with the granite masses or their metamorphic contact zones, but this position is generally further characterized by the presence of post-granitic dykes of quartz-porphyry (Elvan), which, like the lodes, have directions similar to that of the cleavage of the sedimentary rocks which they traverse. As a whole the ores appear to represent the final phase of plutonic activity in the region, the sequence of events being: (1) Intrusion of the granite masses with thermal metamorphism of the slates surrounding them, (2) intrusion of Elvans, (3) formation of the tin and copper lodes accompanied by extensive mineralization of both sedimentary and igneous rocks.

LODE STRUCTURES.

The tin and copper lodes as a whole may be described as fissures of varying size and form, which contain a variety of ores of tin, copper and other metalliferous minerals together with characteristic veinstone accompaniments.

The structure of the lodes indicate to some extent their mode of origin; and while some of them are mere joints or cracks of the thickness of a knife blade, others are of great width and contain much fragmental crushed material indicating that they are probably of the nature of faults.

The variety of structures which the vein stones may assume under such circumstances is fully represented in Cornwall and as a whole may be classified into one or more of the following groups:

1. Fissure, or series of close parallel fissures filled with metalliferous and other minerals.

2. Mineralization of the walls of the lode by impregnation or metasomatic replacement.

3. Mineralization of crushed rock or breccias contained in the lode.

In the first class are included all simple infilled fissures, together with the large workable ore-bearing masses known as stockworks in which a series or group of close parallel fissures often crossed by another series, is worked out as one lode. Stockworks in the granite, killas and elvan are common in all the districts of Cornwall but are not the most profitable types of lodes.

Under the second heading come all the metalliferous portions of the lode which occur as metasomatic replacements of the country rock. As a rule this impregnated zone varies in width from a few inches to a foot or more. It does not yield the highest percentage of mineral but can be profitably extracted with the true lode material. Most of the lodes are associated more or less with this altered band, but abnormal developments known as "Carbonas" sometimes occur. The best known examples of the Carbonas are those of St. Ives and other places in West Cornwall in which long, wide, irregular bodies of schorl, quartz and tinstone occur as an alteration product of the granite

in the vicinity of small fissures running at right angles to the ordinary lodes.

Under the third heading comes the most important of all the lode structures in Cornwall, namely the lodes characterized by breccias and other crushed material of the country rock. In some important mines the width of these brecciated zones varies from a few feet up to many fathoms. The lodes near Camborne and Redruth are typical examples of mineralized breccias but this type of lode occurs in modified form throughout Cornwall. The lodes of the region between Camborne and Penzance generally contain brecciated veinstones, but movements in the lode have resulted in slicken-siding and the rounding of much of the material so that it has now the form of a conglomerate to which the term crush-conglomerate is applied. This leads to a variety of lode structures, composed of breccias and conglomerates cemented by tin stone, copper and iron pyrites, zinc blende, and other minerals, the whole being traversed by strings of quartz, chlorite, fine-grained tourmaline, etc., and constituting the veinstones.

In some brecciated lodes in which very little movement has taken place the rock has merely been comminuted and the lode consists of a mass of interlacing strings of lode mineral.

In some districts the lodes where they traverse the slaty rocks ("Killas") show abnormal developments arising out of the structure of the killas itself. These are the so-called "floors" which although occurring in the St. Just and other mining districts are mostly typically developed at the "Park of Mines" at the western end of the St. Austell granite mass where the tin ore occurs in interbedded layers forming lateral offshoots of narrow veins which cut across the cleavage of the slates. The whole zone in which the layers of tin ore occur was removed bodily.

RELATIONS OF THE ORES OF TIN AND COPPER TO THE GRANITE.

The tin and copper ores occur together in intimate association, but in some important cases these ores occupy different horizons in the lodes. The best known case is that of the lode on the

northern edge of the Camborne granite, extending from Camborne to near Redruth, a distance of over three and a half miles (the Dolcoath Mine Lode). In this lode the ores of copper mixed with tin ore occupy the upper part of the lode and extend from the surface to varying depths down to about 200 fathoms below surface. Below this the principal bodies of tin ore occur to a depth of 500 fathoms from surface. In this case the upper part of the lode is in killas and the lower part is in granite. This zonal arrangement is exhibited in several important mines in Cornwall, among which may be mentioned Levant Mine (near St. Just) where the tin and copper ores occur together in a long "chute" in the sheared killas and greenstone for a mile seaward, parallel with the subterranean surface of the granite and at right angles to its margin. The copper ores at the edge of the granite in Tresavean Mine, near Redruth; the tin and copper mines near St. Austell and other places, illustrate the localization of the ores in certain horizons, the ores of tin and copper occurring either mixed or apart from one another and generally not far from the granite.

In a more general way the Cornish mineral areas are designated tin or copper districts according to the relative proportions in which these minerals occur, but all the districts contain both classes of ores.

NATURE OF THE VEINSTONES.

The veinstones present a large variety in structure and composition, from the simple banded or sheeted structures in simple fissures in which minerals have been successively deposited, to the complex mineralized breccias characteristic of the largest lodes in the county.

In examining the veinstones under the microscope it is seen that they are merely a repetition of the lode structures carried to a microscopic degree of fineness, so that it is unnecessary to describe them again.

In the arrangement of the minerals and in other features the study of the lode material by the microscope affords the information necessary for forming an idea as to their origin.

The ores which enter into the composition of the lode materials

comprise cassiterite, stannite, copper pyrites and dark sulphides of copper, oxides of copper, Fahlerz, carbonate and silicate of copper and native copper; mispickel and other arsenical ores; wolfram, scheelite; phosphates, arsenate and carbonate of lead; silver ores, zinc blende, bismuthine, cobalt and nickel ore, manganese, pitchblende and other ores, among which are embraced various ferriferous minerals.

Among these will be recognized a number which have been formed from alteration (oxidation, etc.) of previous minerals. The others are stable, and are practically incapable of being decomposed under ordinary conditions.

In describing the ores it is important to recollect that they fall into two groups. In the first group is included the original minerals of the lodes such as cassiterite, wolfram, copper and iron pyrites, mispickel and various other sulphides. The second group embraces the ores which originated as a result of the decomposition, migration and redeposition of the primary minerals, including such ores as cuprite, melaconite, native copper, malachite, chrysocolla and various secondary sulphides of copper and other metals.

These secondary ores are confined to the upper parts of the lodes in a zone which may extend to a depth of 200 fathoms from surface. They are easily recognized to have been the last minerals deposited in the lodes as they occur in cracks traversing other minerals, or as incrustations. Some of the carbonates of iron or copper together with pigotite are of such recent origin as to be found encrusting the walls of old levels.

The veinstones, or non-metalliferous gangues, characteristic of the tin and copper lodes of Cornwall are quartz, chlorite, tourmaline, fluorspar and kaolin with other less common minerals.

In describing the microscopic structures of the veinstones it is convenient to divide them into two groups. In the first group is included the material occurring as a deposit in open fissures and, in the second, the veinstones derived by the alteration of the adjacent country rock.

Of the material deposited in the open fissures little need be said since the structures of the veinstones are so largely dependent

on the forms of the openings in which the ores were deposited, as already described.

From the relations of the various ores to one another, however, it appears that the order in which the minerals arrived was as follows:

1. Tin ore, wolfram, sulphides of copper, zinc and arsenic; quartz, fluorspar, chlorite and tourmaline.

2. Copper ores and other sulphides with possibly some silver and lead; quartz, chlorite, fluorspar.

3. Silver-lead ores and carbonates; quartz and fluorspar.

The veinstones derived from the alteration of the country rocks are of more interest since the mineralogical changes which have gone on in the rock through the effects of mineralizing vapors or solutions enable conclusions to be drawn as to the nature of the reactions which took place.

In addition to silicification the granite near the lodes may be tourmalinized, propylitized and greisenized.

The killas or slaty rocks show development of silicified types and tourmalinized bands, while in greenstones garnet is often formed.

PNEUMATOLYTIC ALTERATION AND METASOMASIS.

1. *Granite.*—Granite is the best rock in which to study the changes brought about by pneumatolysis since the coarse-grained nature of its minerals enables the changes to be readily identified.

Tin ore which occurs in such fine pseudomorphs after porphyritic crystals of orthoclase at Huel Coates near St. Agnes is commonly found throughout Cornwall as a partial or complete replacement of the ordinary felspar of the ground mass, while sulphidic minerals such as copper pyrites are frequently found along with tinstone in the decomposed parts of the same crystals or in small cracks traversing the mass.

The changes which the minerals undergo are briefly: (1) A conversion of felspar into lithia-bearing mica or hydrated mica (lepidolite or gilbertite); but also mainly through the action of moisture, the felspar by loss of silicate of potash is extensively, in

some places, converted to china clay, as in the St. Austell region.

The silica liberated during such reactions is deposited elsewhere with the formation of tough silicified rock types.

Where boron vapors have been active there is a conversion of felspar into blue tourmaline which occurs generally as fibrous aggregates. Fluorspar, quartz, tourmaline, copper pyrites, tinstone, topaz, kaolin and pale hydrated or lithia mica all occur as secondary products after feldspar, through the action of original vapors containing fluorine, boron, tin, lithia, sulphur and much moisture.

The mica of the granite is either bleached, with separation of oxide of iron, and conversion to hydrated pale varieties or it may be converted to chlorite with considerable migration of the material. In the ore districts the conversion of biotite to brown tourmaline is universal. These brown crystals are frequently fringed with later growths of acicular blue tourmaline.

The chloritic material and the brown tourmaline are the characteristic alteration products of the biotite.

With the exception of considerable corrosion of the original quartz of the granite this mineral is often quite unaffected. Much secondary silica is produced by the alteration of the rock. This occurs throughout as a granular mosaic where the rock is altered to any extent.

2. *Killas.*—The veinstones occurring in the contact altered sediments surrounding the granite masses have a few features of special interest.

The alteration types include mica schists, and flinty biotite hornfels, andalusite hornfels with exceptional cordierite and pinite. The more gritty bands of the rocks are converted into quartzitic types. In the originally calcareous grit bands tough banded calc-hornfels is produced by contact metamorphism, with development of epidote, axinite, pale pyroxene and garnet.

The modifications of these altered rocks in the vicinity of the lodes are principally those produced by silicification, tourmalinization and impregnation with ores.

Where the slaty rocks are impregnated with tin-ore and sul-

phide of copper the minerals occur in small cracks or along cleavage planes.

As a rule the walls of lodes traversing slates are much crumpled and sheared and there has been an extensive infiltration of quartz which occurs in small lenticles following the contorted cleavage of the slates.

One of the most beautiful and conspicuous of the metasomatic alterations of the killas is that effected by tourmalinization. In the more massive shales the development of tourmaline has taken place for a distance of several inches and even feet on either side of the veins; but where they are banded and consist of alternate thin seams of grits and shales, the tourmaline has only been developed along the impure argillaceous layers, leaving the grit bands quite unaffected. As the rocks are much folded on a small scale, gnarled, sheared and brecciated, all the contortions and general structure of the rocks are preserved and accentuated. In the specimens examined the alteration of the sediments by pneumatolysis has been superimposed on that of contact metamorphism.

In the calc-hornfels bands instead of tourmaline which is only sparingly developed axinite as a product of penumatolytic action on lime-bearing rocks occurs in abundance in association with amphibole, pale and green pyroxene, epidote and garnet. These minerals are well developed in the district north of St. Austell and in the cliffs at St. Just.

3. *Greenstone.*—Like the calc-hornfels the greenstones give rise to lime-bearing minerals such as axinite, fluorspar, epidote, pyroxene and amphibole, and garnet. Tourmaline is uncommon. The garnet occurs in the form of veins which traverse the greenstone like an ordinary veinstone, and in association with it quartz and pyritic minerals are found. By the dim light of the miners' candles this rock has occasionally been sent to surface in mistake for tin-ore in Levant Mine (St. Just).

These garnetiferous veinstones are known to occur in Dolcoath Mine, at Lostwithiel, also on the north of Dartmoor and other places; while they occur abroad in Arizona, Hungary, the Urals, New South Wales and Queensland and in Sweden. In the de-

velopment of the garnet there has probably been an addition of silica to constituents derived from the greenstone, while the changes took place under thermal conditions.

GENESIS OF THE ORES.

The nature of the minerals of the lodes indicates that the vapors and solutions from which the ores were derived contained, in addition to the metals, such materials as fluorine, boron, sulphur, silica, lithia, probably a little carbon dioxide and much moisture. As pointed out long ago by Daubrée and Élie de Beaumont the period at which this type of ore deposits were formed followed closely on the consolidation of the granite mass, the solutions being withdrawn from the magma as it crystallized. In the form of fluorides, sulphides and other compounds the metals and silica were extracted in this way at high temperature and deposited in fissures in the cooler rocks accompanied by the typical mineralization already mentioned.

As elaborated by Professor Vogt, the Cornish ores belong to the subgenetic type, "copper-tin" lodes, or tin lodes characterized by large amounts of copper and other sulphidic ores. The presence of tourmaline recalls the tourmaline copper veins of Mexico on the one hand and the tourmaline wolfram veins of Tirpersdorf (Bohemia) on the other; while the occasional presence of argentiferous galena in the lodes suggests a genetic type having affinities with the Bolivian silver and tin lodes.

The secondary concentration of the sulphidic ores in the upper parts of the lodes has already been referred to. The action of surface waters containing oxygen or carbon dioxide in solution has decomposed original sulphides of the lodes causing them to be carried downwards in the lodes in the form of sulphates or carbonates. Meeting with iron pyrites or other sulphides the sulphates were reduced and the ore precipitated as sulphide.

Secondary enrichments of copper ores in the upper parts of the lodes have yielded in some cases extremely rich bodies of copper ore.

THE SILVER-LEAD VEINS.

The principal lead districts of Cornwall were those of the central and eastern part of the county. That of central Cornwall occurs on the north of Truro while the east Cornwall region is situated in the parishes of Menheniot and St. Ives. In Devonshire the parish of Beerferris was once an important lead producer but like those of Cornwall has been abandoned many years.

The lead districts are situated in the killas at some distance from the granite masses.

The ores occur in a series of approximately north and south cross-courses or faults of tertiary age crossing the general strike of the rocks at right angles and thus belonging to quite a different set of movements to that to which the tin and copper lodes owe their origin.

The richest district has been that of Menheniot and St. Ive, but no lead ores have been raised from it since 1884. The yield of the district between 1848 and 1884 was as follows:

1848 to 1884	Dressed lead ore.....	92,000 tons.
	Metallic lead obtained from the ore....	63,600 tons.
	Silver (parted from lead).....	2,930,000 ounces.

The metalliferous minerals found in association with the lead ores are zinc blende, some copper ore, rich silver ores of various kinds, iron pyrites and mispickel and in one case a few tons of wolfram. The veinstone is composed of quartz, chalybite, calcite and fluorspar. These occur in successive superimposed layers in the lodes, the lead ores being intermediate in age between the first and last of the deposits of the veinstones. The brecciated nature of some of the lodes is a feature worth remarking.

In their genetic relations to the lead lodes of the world they may be regarded as falling into the sulphidic subgroup characterized by quartz, carbonates and fluorspar.

IRON LODES.

Like the lead lodes the iron ores occur in cross courses, but one of the most important of them—the Perran iron lode, near Newquay—has a direction of its own.

Little need be said of these lodes. They are generally of great width but somewhat variable in this. In the upper part they are brecciated and composed largely of hæmatite and limonite with a little manganese ore, while in depth there is a considerable amount of chalybite. Compared with other sources of iron supply these lodes are of no great industrial importance.

ALLUVIAL DEPOSITS OF TIN.

Throughout Cornwall and Devonshire the streams and upland basins or peat mosses draining the mineral districts have been extensively worked in days gone by for tin ore. Lately there has been some attempt to work the same deposits for wolfram which like the tin ore occurs not only as a shoad material, but in the alluvial flats where wolfram lodes are found.

The best known alluvial deposits are those on the north of St. Austell (the Goss Moor, Criggan Moor, Red Moor, etc.), all of which are wide shallow hollows, excavated in what is tentatively considered by Mr. Reid to be an ancient marine shelf sharpened up in Pliocene times at above a level of 400 feet.[1] The largest of these flats is the Goss Moor, one and one-fourth miles in width and three miles in length. The angle of slope is about 0°–30′ towards the stream which drains it so that the gradient is that of torrential conditions. The material in these moors consists of peat, hard subangular stones and finer sands and clays, the tin ore occurring in channels at the base of the deposits. The detritus appears to merge laterally into the broken decomposed surface rock which covers the whole of the west of England and which appears to have been formed under special climatic conditions, probably similar to those of the steppes—cold and dry. As the district has never been glaciated the superficial fragmental rock has been allowed to accumulate, and under special conditions has crept or been washed by rains down the slopes into hollows, whence much of it has found its way into the moors above mentioned.

The alluvial deposits of the rivers draining these flats sometimes attain thicknesses of 30, 40 or 50 feet and consist of alter-

[1] See Lands End Memoir. Explanatory of sheets 351 and 358, 1907, p. 68.

nating beds of sands, clays and layers of peat. At the estuaries the tin ore has been worked below sea level at the bottom of the ancient submerged valleys. In some of the coves round the coast the beach sands have been treated for tin ore.

To the stranger there may be some ambiguity when speaking of the stream-tin. The stream-tin deposits just described are natural alluvial deposits which have been abandoned for many years and are only worked occasionally in a small way; but there is an important industry known as the stream-tin works for saving the tin ore from the tailings or waste thrown into the rivers from the dressing floors of the mines. As much as £40,000 worth of tin ore a year has been collected by the extensive dressing plants or stream-tin works situated on the rivers coming from the active mining districts of Camborne and Redruth.

A GRAPHIC COMPARISON OF THE ALTERATION OF ROCKS BY WEATHERING WITH THEIR ALTERATION BY HOT SOLUTIONS.

EDWARD STEIDTMANN.

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INTRODUCTION.

Hot ore-bearing solutions have been very generally appealed to of recent years as the chief factor in the genesis of the larger

number of metalliferous deposits. Any information that will tend to throw light on the nature of such solutions, the processes by which they have operated and the work which they have accomplished may be expected to materially aid our knowledge of ore-genesis.

The writer has endeavored in the following pages to approach the problem by a graphic comparison of the chemical and mineralogical changes involved in the alteration of rocks by weathering with the changes of the same kinds of rocks effected by the presumably hot solutions on similar rocks adjacent to metalliferous veins. In both cases chemical and microscopical analyses of the original and altered rocks form the basis of comparison.

The processes, agents and results of weathering may be subjected to direct observation and measurement. Our knowledge of weathering, it is true, is far from complete, but still observations are sufficiently numerous to warrant the hope that the nature and work of weathering solutions may be placed upon a quantitative basis. Far less is known regarding the agents, processes and results of thermal solutions. Thermal solutions are active through wide ranges of temperature and pressure, from the hot springs, which issuing at the surface cause certain observable alterations under atmospheric pressure, to aqueous and pneumatolytic solutions, which effect alterations in the depths of the earth under conditions of temperature and pressure which are unknown.

The data at hand regarding the alteration of rocks by hot springs is relatively scanty. Direct observations of the physical and chemical conditions of solutions active in the depths of the earth is impossible. The results of the action of thermal solutions at depth become known only after erosive processes have exposed the regions where they have long since ceased to be active under the same conditions of temperature and pressure, if active at all. From these observed results certain inferences have been drawn as to the agents and the processes which have produced them.

Thus in the Clifton-Morenci district, the thermal solutions have effected a concentration of silica, and various salts, among

them the heavy metals, but have developed almost no carbonates. Lindgren[1] concludes that therefore the solutions themselves were rich in silica and the heavy metals and entirely deficient in carbonic acid.

In this paper an attempt is made to attack the question of the nature of thermal solutions at depth from a new standpoint. The fairly well-known results of weathering are to be used as a standard of measurement against which to gauge the less well-known and more obscure results of the work of thermal solutions with the hope that such a comparison may bring about a clearer understanding of the nature of thermal solutions.

An acknowledgment of the most important bibliographic sources of the data on which this comparison is based will be found at the end of this discussion. The conclusions of Lindgren, Spurr and others regarding the thermal nature of the solutions which have caused certain alterations of the wall rocks adjacent to ore bearing veins are accepted. The mineral compositions given have largely been computed from chemical analyses and mineral descriptions, although some were taken from the cited bibliography. The data available have warranted a comparison of the thermal alterations and weathering of the acid igneous rocks only.

THE ALTERATION OF ROCKS BY HOT SOLUTIONS.

The alterations of the Clifton-Morenci porphyries described by Lindgren in professional paper 43 have been selected as a type of this form of metamorphism. These will be followed by a composite of a series of thermally altered acid igneous rocks. It is to be admitted that any one of the rocks described as thermally altered, may have suffered more or less subsequent modification by weathering. Whether or not this is true, they exhibit certain characteristics which are not produced by simple weathering.

[1] "The Copper Deposits of the Clifton-Morenci District, Arizona," by W. Lindgren, Professional Paper No. 43, U. S. Geol. Sur.

THE CLIFTON-MORENCI MONZONITE PORPHYRIES.

The fresh Clifton-Morenci monzonite porphyries consist of a fine-grained micro-crystalline groundmass of quartz and orthoclase, and accessory amounts of apatite, titanic iron and zircon. Phenocrysts of biotite, albite, oligoclase, orthoclase and quartz are present.

The altered rocks are generally composed of a dense light colored mass of quartz, sericite, sulphides, chlorite, serpentine and accessory minerals. In comparing the fresh rock pound for pound with the altered rock, the chemical changes consist essentially in a loss of all constituents excepting silica, sulphides, potash and water.

Method of Graphic Comparison of Chemical and Mineralogical Changes.

The percentage weights of the chemical and mineralogical constituents of the fresh and altered rocks have been platted as sectors of equal circles. (See Diagrams Nos. I., II.) Alteration may increase certain constituents, leave some unchanged, remove others entirely and introduce new ones in their place. Complete removal of a constituent is represented by a radial arrow projecting from the center of the diagram of the altered rock. By changing the arcs and radii of the sectors representing the composition of the original rock so that the angles subtended by their arcs are equal to the angles subtended by the arcs of the corresponding sectors of the altered rock, and then superimposing the former upon the latter, a perspective of the relative gains and losses of the various constituents can be obtained. Under these conditions the radii of the sectors representing the chemical or mineralogical components are proportional to the square roots of their respective percentage weights. Assuming rock mass constant, then the constituents whose superimposed arcs fall outside of the original circle have suffered loss in proportion to the difference between the areas of their sectors. On the other hand if the arc of a superimposed constituent falls inside the original circle, it follows that the constituent has gained in proportion to

the difference of the areas of the respective sectors representing this constituent in the fresh and altered rock.

The circular diagrams have the further advantage of showing at a glance which of the constituents have lost or gained when any one constituent is assumed to have remained constant. The constituents whose superimposed arcs fall outside of the superimposed constituent assumed as constant have suffered loss, while those which lie inside have gained.

Knowing the volume change of the rock even qualitatively, the positions of the various superimposed arcs with respect to the original circle are an index of the relative degree of constancy of the various constituents.

The percentage values of the sectors of each constituent in the fresh rock as compared with the corresponding sector in the altered rock are given with the tables of analyses.

Chemical Changes of the Clifton-Morenci Monzonite Porphyries.

If a measure of the chemical and mineralogical changes involved in the alteration of the Clifton-Morenci monzonite porphyries is desired, the chemical and mineralogical components of the fresh and altered rocks could easily be platted as sectors of the circular diagrams. Thus silica 68.04 per cent. in the fresh rock No. I. in Table I., page 387, can be platted as a sector whose area is 68.04 per cent. of the area of a circular diagram, and similarly the silica of the altered rock No. III., Table I., can be platted as a sector whose area is 69.55 per cent. of the total area of the circular diagram. By changing the arc and radius of the silica sector of No. I. so that the arc of No. I. subtends the same angle as the arc of No. III., and then superimposing the silica sector of No. I. upon the silica sector of No. III., it is found that the arc of the superimposed silica sector falls inside of the circumference of the circle. The sectors of all the other constituents of the fresh rock can be changed in a similar manner and superimposed upon the corresponding sectors of the altered rock. This is done in Diagram I. From Diagram I., it is possible to estimate directly (1) the amount of gain or loss of each con-

stituent assuming rock mass constant (2) the amount of gain or loss in rock weight assuming any one constituent as constant, and (3) the gain or loss of individual constituents assuming any one constituent as constant.

1. *The Amount of Gain or Loss of Individual Constituents Assuming Rock Mass Constant.*—By the assumption of constancy of rock mass it is meant that one hundred pounds of the fresh rock will weigh exactly one hundred pounds when altered. One hundred pounds of fresh Clifton Morenci monzonite porphyry contain 68.04 pounds of silica, while the altered rock No. 3 contains 69.55 pounds. The weight of silica in No. I. is 98 per cent. of the weight of silica in the altered rock; that is, an addition of 2 per cent. of silica has taken place. This increase can be read directly from Diagram I. The silica arc of No. I. delimits 98 per cent. of the silica sector of No. III.

Similarly the iron sulphide arc of the original rock delimits 7.7 per cent. of the iron sulphide sector of No. III., the altered rock.

The potash arc of No. I. delimits 77.7 per cent. of the potash sector of the altered rock No. III. in Diagram I., therefore potash has gained 32 per cent. of its own weight.

In the same diagram, the copper sulphide arc of the fresh rock delimits 28.6 per cent. of the copper sulphide sector of the altered rock, No. III.

The soda arc of the fresh rock in Diagram I. is seen to delimit 3,130 per cent. of the soda sector of No. III. It follows that the loss of soda is $(3{,}130 - 100)/3130$, or 98 per cent. of its original weight.

The lime arc of the fresh rock is 1,470 per cent. of the lime sector of the altered rock No. III. in diagram I., therefore the loss of lime amounts to $(1470 - 100)/1470$, or 93 per cent. of the original lime content.

It is important to keep in mind that the above conclusions hold only under the assumption of constancy of rock mass.

2. *Gain or Loss in Rock Mass Assuming any one Constituent as Constant.*—In Diagram I., it has been seen that the arc of the potash sector of the fresh rock includes only 77.7 per cent.

TABLE I

CHEMICAL COMPOSITION OF FRESH AND ALTERED MONZONITE PORPHYRY, CLIFTON-MORENCI DISTRICT. (Lindgren, Prof. Paper 43, U. S. Geological Survey, pp. 167–168.)

	Fresh. I.	Alt. II.	$\frac{I.}{II.}$	Alt. III.	$\frac{I.}{III.}$	Alt. IV.	$\frac{I.}{IV.}$	Alt. V.	$\frac{I.}{V.}$
SiO_2	68.04	46.67	114.5	69.55	98	64.88	105	72.78	93.5
Al_2O_3	17.20	20.92	82.50	16.43	105	16.41	105	15.35	112
Fe_2O_3	.34	.37	92	.46	74	.65	?	.55	62
FeO	.67	.36	186	.11	557			.10	570
MgO	1.05	.85	123	.62	169	1.12	94	.89	118
CaO	2.21	.15	1470	.15	1470	.11	2000	.14	1580
Na_2O	5.33	.16	3550	.17	3130	.12	4440	.36	
K_2O	2.65	4.33	90.7	5.05	77.7	4.96	79	5.00	78.5
H_2O-	.60	.94	63.9	1.00	60	.83	72.3	1.21	49.5
H_2O+	1.23	5.01	24.5	2.69	45.7	2.74	45	3.22	38.2
TiO_2	.41	.43	95.5	.41	100	.38	108	.45	95
P_2O_5	.12	.15	80	.05	240	.12	100	.05	240
CO_2	none								
S									
SO_3									
FeS_2	.24	19.18	.125	3.09	7.76	4.96	4.84	.06	400
Cu_2S	.02	.24	.84	.07	28.6	2.42	.82		
Fe	.76	8.50	8.90	2.00	38	2.59	29.3	.46	165

of the area of the potash sector of the altered rock, No. III. If potash has remained constant, it would mean that 77.7 pounds of the altered rock contains as much potash as one hundred pounds of fresh rock, and that the altered rock has lost 32.3 pounds of constituents other than potash per one hundred pounds of fresh rock.

If lime is assumed to have remained constant in Diagram I., it would follow that the rock mass had received an addition of 1,370 pounds of materials other than lime per 100 pounds of fresh rock. The lime arc of the lime sector of the fresh rock includes 1,470 per cent. of the area of the lime sector of the altered rock; that is, 100 pounds of fresh rock contain as much lime as 1,470 pounds of the altered rock, consequently the assumption of lime constancy involves an addition of 1,370 pounds of materials per hundred pounds of fresh rock.

3. *Gain or Loss of Individual Constituents Assuming any one Constituent as having Remained Constant.*—It has been stated that 100 pounds of fresh rock contain as much potash as

77.7 pounds of the altered rock in Diagram I., and that 100 pounds of altered rock contain 69.55 pounds of silica. Assuming potash constant 100 pounds of fresh rock on altering to No. III. would contain only 77.7 per cent. of 69.55 pounds, or 54 pounds of silica. The silica loss involved in the process of alteration is 68.04 — 54, or 14 pounds of silica per one hundred

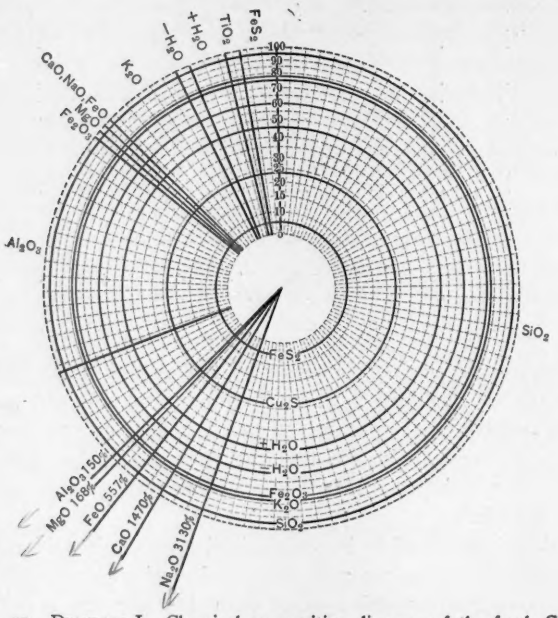

FIG. 29. DIAGRAM I. Chemical composition diagram of the fresh Clifton-Morenci porphyry No. I. and the thermally altered phase No. III.

pounds of fresh rock. The percentage loss of silica with potash constant is therefore 14/68.04, or 20.3 per cent. of its original weight.

For clearness, the above problem is given a brief mathematical statement.

Silica in 100 pounds of fresh rock equals 68.04 pounds.

100 pounds of fresh rock alters to 77.7 pounds of altered rock No. III.

77.7 pounds of altered rock contain 54 pounds of silica.

The silica loss per 100 pounds of fresh rock is 69.55 — 54 or 14 pounds.

The loss per cent. in silica is 68 — 54/68, or 20.3 per cent.

Diagram I. shows that 100 pounds of fresh rock contain as much silica as 98 pounds of altered rock. The silica in one hun-

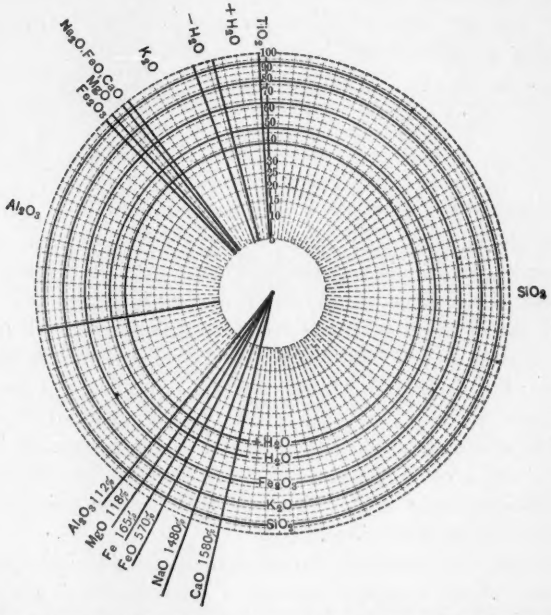

FIG. 30. DIAGRAM II. Chemical composition diagram of the fresh Clifton-Morenci porphyry No. I. and the thermally altered phase No. V.

dred pounds of fresh rock can be stated 98 per cent. of 69.55. Assuming potash constant the weight of silica in the altered rock resulting from the alteration of 100 pounds of fresh rock can be expressed as 77.7 per cent. of 69.55.

The following statement can be made of the problem of silica loss with potash constant.

Pounds of silica in 100 pounds of fresh rock equals 98 per cent. of 69.55.

Pounds of silica in the altered rock resulting from the alteration of 100 pounds of fresh rock equals 77.7 per cent of 69.55.

The loss of silica involved in the alteration of 100 pounds of fresh rock assuming potash constant is (98 per cent. 69.55) — (77.7 per cent. 69.04).

The loss per cent. of silica per 100 pounds of fresh rock assuming potash constant is

$$\frac{(98 \text{ per cent. } 69.55) - (77.7 \text{ per cent. } 69.55)}{(98 \text{ per cent. } 69.55)} =$$

$$\frac{98 - 77.7}{98} = 20.3 \text{ per cent.}$$

The above demonstration points out a simple method of determining the percentage gain or loss of any constituent when any one constituent is assumed constant. 98 is the percentage intercept of the silica arc of the fresh rock in Diagram I., and 77.7 is the intercept of the potash arc of the fresh rock in the same diagram. The following simple rule can therefore be formulated: For determining the percentage gain or loss of any one constituent when some other constituent is assumed to have remained constant. Take the difference of the percentage intercepts of the arcs of the respective constituents, and divide by the intercept of the arc of the constituent whose gain or loss per cent. is to be determined.

Following this general interpretation of the chemical changes expressed by the circular diagrams, a brief résumé is given of the chemical and mineralogical changes involved in the alteration of the Clifton-Morenci wall rocks adjacent to ore-bearing veins. The same general interpretation applies to the mineralogical changes expressed by the diagram as for the chemical changes.

1. Assuming rock mass constant, the altered rock No. III., Diagram I. has lost soda, lime, ferrous iron, magnesia, and alumina in the order mentioned. Silica, potash, ferric iron, both free and combined water, copper sulphide and iron sulphide

have gained, the latter showing the largest gain and silica the least.

In rock No. V., Diagram II., which marks an extreme stage of alteration, the same assumption involves a loss of lime, soda, ferrous iron, magnesia, alumina and an increase of silica potash,

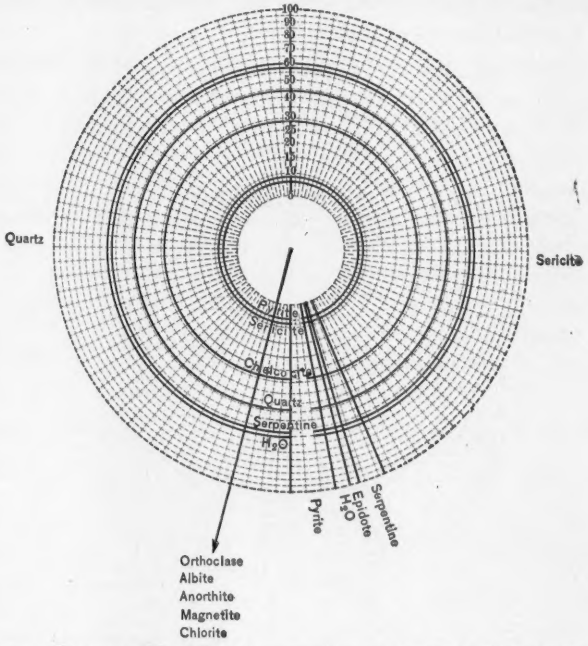

FIG. 31. DIAGRAM III. Mineral composition of the fresh Clifton-Morenci monzonite porphyry and the altered rock No. III.

ferric iron and both free and combined water. Lime is the most soluble, and water has received the largest increase.

2. Under the assumption that either silica, potash, ferric iron, both free and combined water, copper sulphide and iron sulhpide are constant the alteration of rock No. III. involves loss of material per unit volume of fresh rock. On the other hand assuming alumina, magnesia, ferrous iron, lime or soda

constant would involve a considerable gain in weight per unit volume of fresh rock. The altered rock is slightly more porous than the fresh rock, and the mineral specific gravity of the altered rock is higher than that of the fresh rock when the increase in sulphides is considerable as in Rock No. III. The conclusion is therefore warranted that both introduction and loss of materials has taken place.

Diagram II. shows the same general relation as Diagram I.

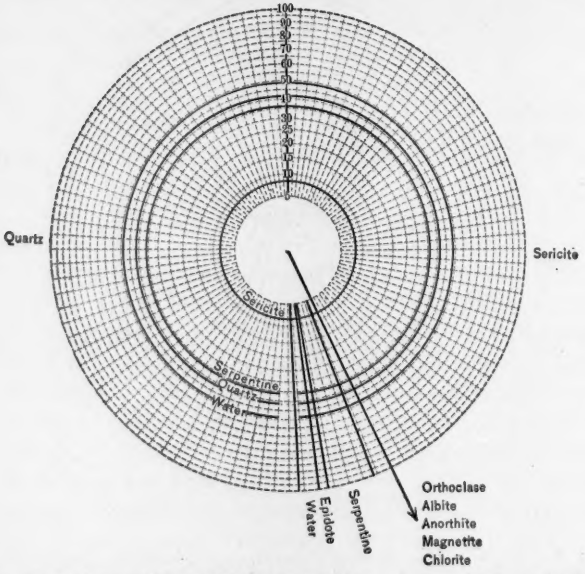

FIG. 32. DIAGRAM IV. Mineral composition of the fresh and altered Clifton-Morenci monzonite porphyry No. V.

only that in the extreme stage of alteration, silicification is more important than the increase in sulphides.

3. Assuming silica constant in Diagrams I. and II. would involve gain in potash, ferric iron, both combined and free water, and a loss of alumina, magnesia, ferrous iron, lime and soda. Diagram I. shows a large increase in sulphides. The assump-

tion of constancy for potash indicates loss of silica and a gain or loss of all other constituents in the same order as under silica constant. Finally if the sulphides are regarded as constant in Diagram I., all the other constituents have suffered loss.

Mineralogical Changes of the Clifton-Morenci Monzonite Porphyries.

The mineralogical changes expressed by the diagrams are decomposition of the feldspars, magnetite, ilmenite and chlorite. The titanium dioxide of ilmenite assumes the form of rutile; the potash orthoclase becomes a part of the secondary sericite, and magnetite alters to pyrite. Serpentine takes up the magnesia in the altered rock and is secondary after the chlorite which in turn is a product of decomposition. Kaolin does not appear to be a thermal alteration product and this accounts for the decrease in alumina. As soon as the bases have been removed to such an extent that all the aluminium cannot enter into combination as a baso-alumino silicate, its removal becomes necessary, since it

TABLE II.

MINERAL CONTENT OF FRESH AND ALTERED CLIFTON-MORENCI MONZONITE PORPHYRIES.

	I.	II.	$\frac{I.}{II.}$	III.	$\frac{I.}{III.}$	IV.	$\frac{I.}{IV.}$	V.	$\frac{I.}{V.}$
Orthoclase	13.12								
Albite	45.26								
Anorthite	9.52								
Apatite	.28	.36	78	.12	233	.30	.93	.12	233
Zircon	.02								
Magnetite	.41								
Ilmenite	.81								
Rutile		.43		.41		.38		.45	
Sericite	3.75	38.50	9.75	43.44	8.65	44.94	8.35	44.29	8.40
Kaolin		17.90							
Chlorite	3.04								
Serpentine	.98	2.81	34.8	1.71	57	2.74	35.8	2.71	36
Epidote	.59			.43				.36	
Alunite		.46		.26		26.		.21	
Water	.60	.94	64.4	1.00	60	83.	.72	1.21	49.5
Pyrite	.24	19.18	.125	3.09	7.8	4.96	4.85	.06	400
Chalcocite	.02	.24	8	.07	28.6	2.42	.32		
Sphalerite	.03	.32							
Molybdenite		.20							
Quartz	21.35	19.13	110	49.33	42.8	43.03	49.00	50.81	41.50

Mineral analysis by Lindgren.

apparently cannot assume any other stable form. Kaolinic veins appear in No. II., but these do not contain pyrite. Since pyrite, sericite and quartz constitute an intimate mixture in the altered rock, indicating contemporaneous processes, the absence of pyrite in the kaolinic veins leads to the inference that their genesis is different from that of the altered, adjacent country rock.

Kaolin is an abundant alteration product of vadose solutions, and therefore the evidence is strong in favor of the superposition of kaolin upon earlier thermal alteration products by processes of weathering.

COMPOSITE OF ACID IGNEOUS ROCKS ALTERED BY HOT SOLUTIONS.

The Clifton-Morenci monzonite porphyries have furnished a type of rock alteration by hot solutions. Attention is now directed to the study of composites made up from eight analyses of fresh acid igneous rocks, and seventeen analyses of thermally altered acid igneous rocks from the Tonopah, Clifton-Morenci, Bingham, Willow Creek, Pilbara and Cripple Creek districts. Tables III. and IV. give the chemical and mineralogical compositions of the composite fresh and altered rocks, and diagrams V. and VI. present a graphic illustration of the chemical and mineralogical changes.

Chemical Changes.—On comparing diagram V. representing the chemical changes involved by the alteration of the composite acid igneous rocks by hot solutions with diagrams I and II. representing the changes which the Clifton-Morenci monzonite porphyries have undergone, it is observed that the changes in both cases are essentially the same. The superimposed constituents whose arcs fall within the circle are essentially the same in both cases. It necessarily follows that the superimposed constituents whose arcs fall outside the circle are also the same in both cases. The arcs of the superimposed constituents, while bearing a relatively constant relation to the circumference of the circle, do not bear a constant relation to each other. They change their position with respect to each other. It is there-

fore evident that the alteration of rocks by thermal solutions lacks rigid uniformity. Certain constituents are, however uniformly concentrated; that is, the arcs of their superimposed sectors persistently appear on the inside of the circular diagram. Other constituents are persistently unstable; that is the arcs of their superimposed sectors uniformly appear on the outside of the circle. The relative rates with which the various constitu-

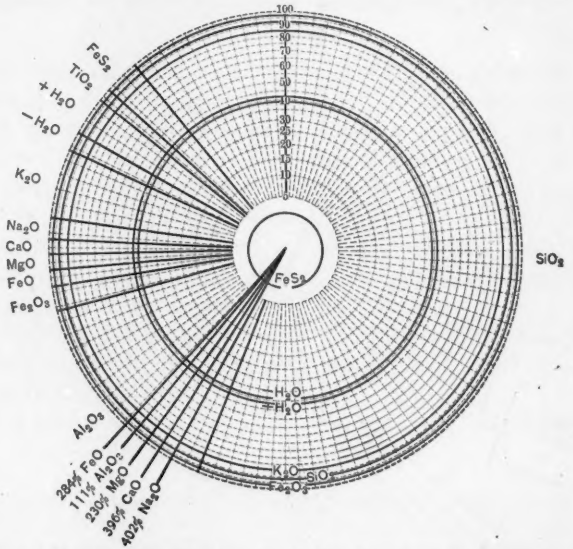

FIG. 33. DIAGRAM V. Diagram illustrating the chemical changes involved in the alteration of an average acid igneous rock by thermal solutions.

ents are concentrated or eliminated is variable, and therefore the arcs delimiting the superimposed sectors shift their position with respect to each other.

Since the chemical changes of the composite acid igneous rock altered by hot solutions are essentially the same as in the Clifton-Morenci district, it is needless to repeat in detail the nature of these changes.

Mineralogical Changes.—The mineralogical changes of the

composite acid igneous rocks effected by hot solutions, like the chemical changes are in essential agreement with mineralogical changes of the Clifton-Morenci porphyries, as will be seen by a comparison of diagrams III. and IV. with diagram VI. Magnetite and the original ferromagnesian silicates are rapidly decomposed. The plagioclase feldspars are more or less decomposed depending upon the degree of alteration. Orthoclase is

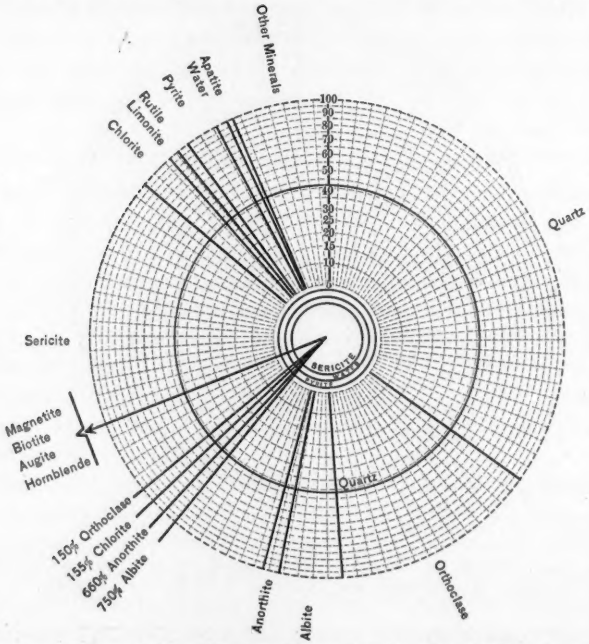

FIG. 34. DIAGRAM VI. Diagram illustrating the mineralogical changes involved in the alteration of an average igneous rock by thermal solutions.

on an average less readily decomposed, and in the Cripple Creek and Tonopah districts, it occurs as a secondary mineral. Albite is known to occur as a secondary mineral resulting from hot solutions, but has not been found in the districts under discussion.

Chlorite occurs more or less abundantly, and is usually the

most stable form assumed by magnesia under the action of hot solutions.

Titanite is altered to rutile, and pseudomorphs of pyrite after magnetite are common.

The minerals whose secondary development as a result of hot solutions is conspicuous are quartz, sericite and sulphides.

Conclusions on the Alteration of Acid Igneous Rocks by Hot Solutions.

The individual diagrams as well as the composites of the chemical and mineralogical changes of seventeen acid igneous rocks from the Pilbara, Tonopah, Clifton-Morenci, Bingham, Willow Creek and Cripple Creek districts, Diagrams V. and VI., justify the following conclusions on the alteration of acid igneous rocks in the cases under consideration:

1. The alteration of rocks by thermal solutions lacks rigid uniformity; that is the relative solubility or concentration of various constituents is variable.

2. Both introduction and removal of materials takes place. *Certain substances are uniformly stable while others are persistently unstable.*

The predominant chemical changes are a progressive increase

TABLE III.

COMPOSITION OF COMPOSITES OF FRESH AND ALTERED ACID IGNEOUS ROCKS FROM WALLS ADJACENT TO ORE-BEARING FISSURES. The composite of the fresh rocks is an average of eight analyses, the composite of the altered of seventeen analyses from the Tonopah, Clifton, Bingham, Willow Creek, Pilbara and Cripple Creek districts.

	Fresh	Altered.	Fresh Altered.		Fresh.	Altered.	Fresh. Altered.
SiO_2	61.73	66.40	92	H_2O-	.44	1.15	38
Al_2O_3	16.42	14.80	111	H_2O+	1.06	2.52	40
Fe_2O_3	1.73	1.67	104	TiO_2	.69	.54	126
FeO	2.84	.92	284	P_2O_5	.14	.14	100
MgO	2.16	.94	230	CO_2	.45		
CaO	3.56	.90	396	S			
Na_2O	4.28	1.10	402	SO_3			
K_2O	4.03	4.76	84	FeS_2	.06	2.29	2.60
				Fe	3.40	2.95	114

TABLE IV.

MINERAL ANALYSIS OF THE AVERAGE FRESH AND ALTERED ACID IGNEOUS ROCKS FROM WALLS ADJACENT TO ORE-BEARING FISSURES. Source of the same as Table V.

	Fresh.	Altered.	Fresh Altered.		Fresh.	Altered.	Fresh. Altered.
Quartz	14.40	35.07	41	Apatite	.48	.28	171
Orthoclase	21.20	14.27	150	Titanite	.95		
Albite	32.22	4.31	750	Biotite	6.44		
Anorthite	8.00	1.21	660	Augite	2.59		
Sericite	3.73	31.86	1.17	Hornblende	3.70		
Chlorite	3.70	2.40	155	Pyrite	.08	2.29	3.50
Limonite		.67		Rutile		.55	
Magnetite	2.09			Water	.60	.61	100

Minerals entirely decomposed; magnetite, biotite, hornblende, augite and titanite.

in potash and silica, and a progressive elimination of soda, lime, magnesia, ferric oxide, ferrous oxide, iron and alumina. Of the constituents removed, soda is generally the most soluble. The solubility of the others follows in the order in which they are named, lime being by far the most soluble. Oxidation appears to increase ferric iron at first, but the general tendency is for the removal of both ferric and ferrous iron. Alumina is the most refractory of the substances removed, but generally passes out as soon as the bases necessary for the existence of basic-aluminium silicates are removed. Kaolinite is only exceptionally developed and it is a mooted question whether it ever is a normal product of thermal alterations or whether it is superimposed upon the latter by the agencies of weathering.

Hydration is at first important but necessarily diminishes after a certain elimination of bases has taken place.

Sulphides, especially pyrite, are introduced. Wherever their introduction is abundant, they tend to increase the mineral volume of the rock mass.

4. The predominant mineral changes are silicification, sericitization and the development of sulphides, especially pyrite.

In general chlorite is the most stable form assumed by magnesia and iron under the conditions, although there are some apparent exceptions.

Orthoclase may be decomposed or it may occur as a secondary mineral. In general the former is the more important process.

Amphiboles, pyroxenes, magnetite, biotite and titanite are readily decomposed. Titanite alters to rutile, and magnetite changes in part at least to limonite and pyrite.

The lime-soda feldspars are always more or less decomposed depending upon the degree of alteration.

5. The net result of the alteration of acid igneous rocks by thermal solutions involves molecular simplification, and slight net increase in mineral density depending upon the introduction of heavy sulphides.

THE ALTERATION OF ROCKS BY WEATHERING.

The weathering of acid igneous rocks is given detailed attention in order to make a comparison with the chemical and mineralogical changes effected by hot solutions. Attention is also called to the weathering of basic igneous rocks to show the dependence of these changes upon the constitution of the rocks themselves. The weathering of individual specimens is not brought under discussion. The results of weathering are remarkably uniform and therefore it is more instructive to consider the chemical and mineralogical changes of composites made up from a number of analyses.

METHOD OF OBTAINING AVERAGE COMPOSITIONS OF THE WEATHERED ROCKS.

Average compositions of the fresh acid or basic igneous rocks may be found by direct summation, but this method is open to criticism when used for finding the average composition of weathered rocks, since the rates with which the various soluble constituents are lost vary with the degree of alteration. A true average composition of the weathered rocks is based on an average of the rates of loss.

A fairly satisfactory method of finding average compositions of weathered rocks on the basis suggested is by platting all the original compositions of the weathered rocks on one ordinate as shown for silica and alumina in Fig. 35.

Alumina is regarded as constant relatively in weathering and therefore its rate of increase is represented by parallel, ascending lines of convenient slope. The abscissæ of the ordinates on which the compositions of the weathered rocks are platted are therefore controlled by the increase in alumina, or the degree

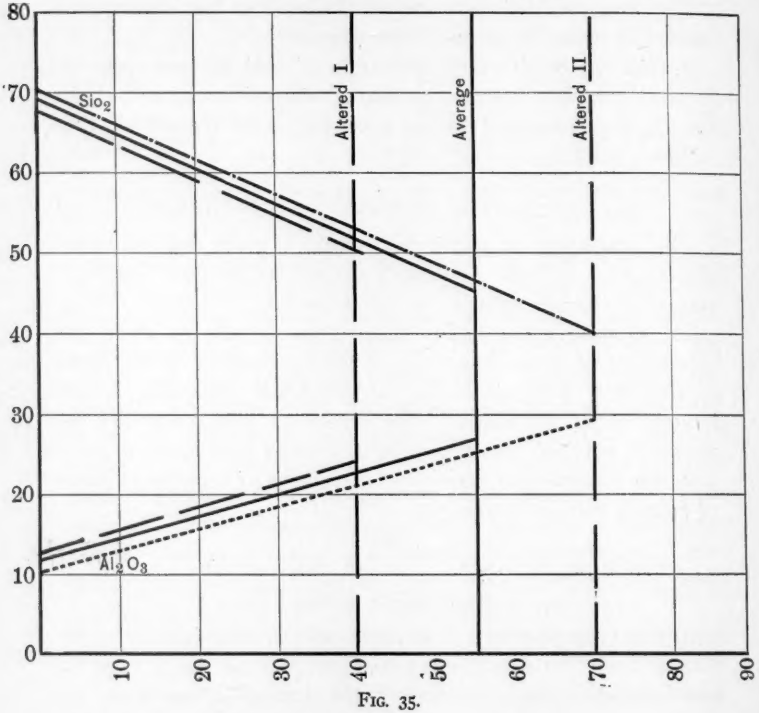

FIG. 35.

of alteration. The descending slopes of the lines connecting the soluble constituents of the fresh and weathered rocks, as shown for silica in Fig. 35, represent the rates of loss of the constituents in the various stages of decay, and an average of the slopes of each constituent, as shown by the continuous lines in Fig. 35, is an average rate of loss. When these average slopes

are platted with an average of the original compositions, an average composition of the weathered rocks is obtained by finding the intercepts of the slopes on ordinates chosen with respect to the desired degree of alteration.

TABLE V.

FRESH GRANITIC ROCKS AVERAGE OF EIGHT GEORGIA GRANITES. (Bull. 9 a, Georgia Geological Survey, and one District of Columbia granite.) An intermediate stage of alteration is assumed.

	Fresh.	Altered.	Al_2O_3 Const.	Rock Loss.	Rock Gain.	Constituents.		Fresh. Altered.
						Loss.	Saved.	
SiO_2	68.80	63.90	48.90	19.9		29.8	71.2	107
Al_2O_3	16.30	21.30	16.30				100	76.5
Fe_2O_3	1.90	2.89	2.21		.31		100	65.8
FeO								
MgO	.70	.31	.24	.46		65.7	34.3	226
CaO	2.30	.06	.05	2.25		97.9	2.10	4600
Na_2O	3.80	1.75	1.34	2.46		64.8	35.2	217
K_2O	4.80	3.40	2.60	2.20		45.8	54.2	141
H_2O—								
H_2O+	.50	5.70	4.36		3.80		100	8.90
TiO_2								
P_2O_5								
CO_2								
S								
SO_3								
	99.1	99.2	76.00					

CHEMICAL CHANGES IN THE WEATHERING OF AN ACID IGNEOUS ROCK.

The original average acid igneous rock, Diagram VII., Table V., is composed of eight granites of Georgia, and one from the District of Columbia. Its moderately weathered product was found by the method of average slopes.

The chemical changes indicated by the diagrams hold for the individual rocks as well as for the composites. They consist in a loss of all constituents excepting alumina, ferric oxide and water. Alumina and ferric oxide remain about constant. Water is added.

The following table shows the ratio of the solubilities of the various oxides assuming alumina constant:

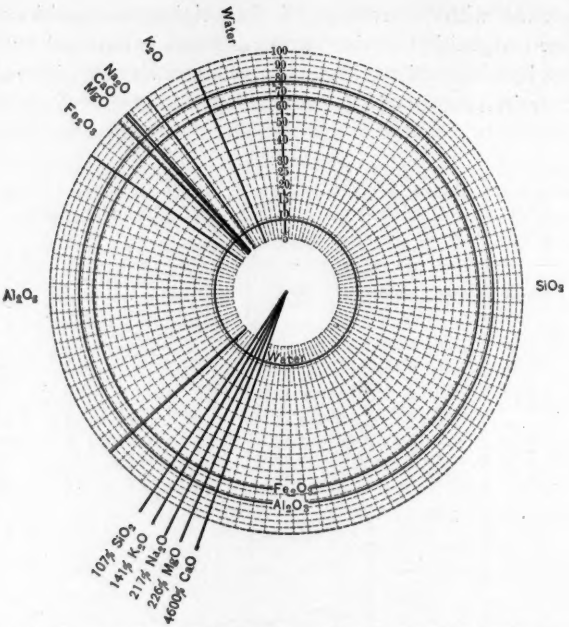

FIG. 36. DIAGRAM VII. Diagram showing the chemical changes from an average acid igneous rock to a weathered equivalent.

Combined silica	1.00
Pótash	1.03
Soda	1.60
Magnesia	1.62
Lime	2.41
Alumina	00

CHEMICAL CHANGES IN THE WEATHERING OF BASIC IGNEOUS ROCKS.

The chemical changes indicated by Table VI. of the basic igneous rocks hold for the individual rocks as well as for the composite. Competent students of metamorphism have found that alumina suffers practically no change in the weathering of rocks, so far as chemical processes are concerned. Assuming

alumina constant, ferric oxide and water have gained. The increase in ferric iron comes from the oxidation of ferrous silicates. The complete decomposition of the latter results in a loss of iron. Taking alumina as unchanged the ratio of solubilities is as follows:

Silica	1.00
Potash	1.66
Soda	1.70
Lime	1.85
Magnesia	1.95
Alumina	∞

The order of solubility is the same as in the acid igneous rocks, excepting that in basic rocks high in magnesia, the latter is generally more soluble than lime.

TABLE VI.

AVERAGE OF FIVE FRESH AND WEATHERED BASIC ROCKS FROM MERRILL'S ROCK WEATHERING, etc., viz., diabase from Spanish, Guiana; Medford, Mass.; basalt from Bohemia, Crouzet, France, diorite from Albemarle Co., Va.

	Fresh.	Altered.	Fresh Altered.	Altered. Al_2O_3 Const.	Losses.	Gains.	Per Cent. Saved.	Per Cent. Lost.
SiO_2	47.00	42.50	110	29.90	17.00		63.8	36.20
Al_2O_3	15.70	21.60	72.6	15.70			100	
Fe_2O_3	4.78	17.00	28.10	11.98		7.20	100	
FeO	9.96							100
MgO	6.36	2.70	235	1.90	4.46		29.8	70.1
CaO	8.96	4.20	213	2.96	6.00		33	67.0
Na_2O	2.77	1.50	187	1.06	1.71		38.3	61.7
K_2O	1.23	.70	177	.49	74		39.8	60.2
H_2O-								
H_2O+	3.24	9.80	34.1	6.80		3.56		
TiO_2								
P_2O_5								
CO_2								
S								
SO_3								
	100	100						
Fe	11.10	11.19	100	8.14	2.96		73.50	26.5

MINERALOGICAL CHANGES INVOLVED IN THE WEATHERING OF THE ACID AND BASIC IGNEOUS ROCKS.

Table VII. gives the mineral composition of an average crystalline rock computed from Clarke's analysis of an average

igneous rock. It also gives the mineral composition of its completely weathered equivalent assuming all the materials to have remained in situ, and to have reached their most stable form under katamorphic conditions.

The end products of weathering are essentially quartz, kaolin, and the carbonates of lime and magnesia. Sodium and potassium occur as chlorides in the sea, in their final form as products of weathering. The iron reaches its most stable form as hydrated hematite or limonite.

Weathering results in the molecular simplification of minerals as is shown by the transformation of more or less complex silicates into simple oxides, carbonates and hydrates. It also involves slight net decrease in mineral density.

TABLE VII.

MINERALOGICAL COMPOSITION OF AN AVERAGE CRYSTALLINE ROCK, AND ITS COMPLETE WEATHERED EQUIVALENT, ASSUMING ALL THE MATERIALS TO HAVE REMAINED IN SITU. From computations based on Clark's average crystalline rock analysis, U. S. Geol. Survey, Bull. 288, p. 18.

	Fresh.	Weathered.
Quartz	11.00	33.12
Albite	28.00	
Anorthite	18.00	
Orthoclase	17.00	
Diopside	7.00	
Hypersthene	11.00	
Magnetite	7.00	
Mica	1.00	
Calcite		8.26
Kaolin		32.03
Magnesite		6.65
Limonite		11.20
Sylvite		3.88
Halite		4.86
	100.00	100.00

THE RELATION OF THE RATIO: $\frac{\text{BASES}}{\text{COMBINED SILICA}}$ TO RATIO: $\frac{\text{BASES LOST}}{\text{SILICA}}$

The ratio of the bases in the acid igneous rocks, including lime, soda, magnesia, potash and some ferrous iron to combined

silica is 11.6:48.8 or 1:4.2. The ratio of the loss of these bases to the loss of silica, as shown by Fig. 2 is 1:2.7.

In the basic igneous rocks the ratio of the bases magnesia, lime, soda, potash, some ferrous and ferric iron to the silica with which they are combined is 24:47 or 1:1.95. The ratio of their losses is 1:1.09. The preceding ratios are based on

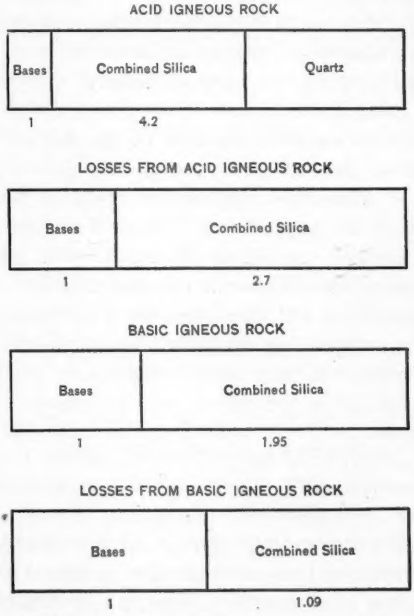

FIG. 37. Illustrating the ratios between combined silica and bases in the acid and basic igneous rocks and their losses as shown by the composites and the individual analyses.

computations made on the composites given in this article and on the individual analyses.

On comparison of the ratios with which bases and silica are combined in the acid and basic igneous rocks, to the ratio of their losses, it appears that the silica lost by solution on decomposition of a silicate is directly proportional to the ratio of

combined silica to bases. In acid igneous rocks about twice as much silica is combined with a given weight of bases as in the basic igneous rocks. The loss of silica to the percentage of bases lost is about twice as great in the acid igneous rocks as in the basic. This relation between the ratio of combined silica to bases in the igneous rocks is interpreted as a sequence of the law of mass action. The bases in the acid igneous rocks which are combined with silica in the ratio of approximately 1 : 2 adhere about twice as tenaciously to their silica as the bases of the acid igneous rocks, in which the ratio of bases to combined silica is about 1 : 4.

In the study of the redistribution of the elements from the original rocks to the sediments, the knowledge of this relation is a matter of paramount importance. The solutes resulting from rock decay are supposed to furnish the materials for the chemical precipitates, cementing materials, vein materials and salts of the sea. This raises the question whether the mass of chert, for instance, in the limestones bears any fixed relation to the lime content, depending upon the original constitution of the rocks from which the lime was derived. A similar relation should be looked for in the cherty iron formations.

SUMMARY OF WEATHERING.

1. The chemical and mineralogical changes effected by weathering are markedly uniform.

2. Weathering results in the loss of all constituents excepting water. Alumina and ferric iron are lost to such a slight extent that for purposes of comparison, they can be regarded as constant. Water receives considerable addition. The order in which the constituents are lost is lime, magnesia, soda, potash, silica, iron and alumina. In very basic rocks the rate of loss of magnesia may exceed that of lime.

3. The mineralogical changes involved in weathering of igneous rocks consists in the decomposition of the silicates into simple oxides, carbonates, hydrates and chlorides, which are essentially quartz, the carbonates of lime and magnesia, kaolin and limonite and the chlorides of soda and potash. These changes are ac-

companied by molecular simplification and slight net decrease in mineral density.

4. In the weathering of igneous rocks, the proportion of bases to silica lost is determined by the ratio in which silica and bases are combined.

COMPARISON OF WEATHERING AND THERMAL ALTERATION.

This comparison relates to the specific alterations which have been here considered. The general conclusions as stated for weathering are believed to apply to all changes produced by weathering, allowing only minor modifications. To what extent the conclusions relating to the alteration of rocks by thermal solutions apply to all changes of this nature is uncertain. This comparison refers to the acid igneous rocks only.

1. The alteration of rocks by weathering is characteristically uniform, being based upon silicate ratios. Lack of uniformity is peculiar to the alteration of rocks by thermal solutions.

2. The loss of silica and bases in the weathering of rocks is controlled by the ratio in which silica and bases are combined. No such relation is observed in the alteration of rocks by hot solutions.

3. In weathering, solution dominates. With the exception of the addition of water, carbon dioxide and oxygen, no essential introduction of materials takes place. Thermal solutions alter rocks by addition and subtraction of materials.

4. Carbonation, hydration and oxidation are the dominant processes in weathering. They are generally subordinate in the changes affected by hot solutions. Silicification and sericitization stand out boldly as characteristic changes involved by the action of the latter.

5. The constituents removed by weathering are lime, magnesia, soda, potash, silica and ferrous oxide. In general soda is by far the most soluble constituent when alterations are caused by thermal solutions. Lime, magnesia, ferrous oxide and alumina follow in the order given. Alumina is nearly always removed when the bases necessary for the existence of basic aluminium silicates have been removed. It is inferred that the exceptions

to this rule may be due to normal weathering superimposed upon changes caused by thermal solutions. Potash sulphides and silica are increased. Total iron is decreased. Hydration is important until the elimination of bases has progressed beyond a certain stage.

6. The characteristic minerals of weathering are oxides, carbonates, hydrates and chlorides, such as quartz, limonite, carbonates of lime and magnesia, kaolinite, and the chlorides of soda and potash. Their development involves molecular simplification and slight net loss in density. The minerals which are peculiar to thermal alterations are sericite, quartz, sulphides, sometimes secondary orthoclase, and to a subsidiary extent chlorite and other accessory minerals. Chlorite is generally the most stable form assumed by magnesia compounds under these conditions. The mineral development involves molecular simplification and usually a slight net gain in mineral density as a result of the introduction of sulphides. A tabulation of the changes involved in the alteration of acid igneous rocks by weathering and by hot solutions is given below.

TABULATION OF THE CHANGES INVOLVED IN THE WEATHERING OF ACID IGNEOUS ROCKS AND THEIR ALTERATION BY HOT SOLUTIONS.

Chemical Changes.

Weathering.	*Hot Solutions.*
Oxidation important.	Oxidation subordinate.
Carbonation important.	Carbonation subordinate.
Hydration important.	Hydration subordinate.
Loss of all constituents excepting alumina, ferric oxide and water. Water is introduced.	Loss of soda, lime, magnesia, ferric oxide, ferrous oxide, iron and alumina. Concentration or introduction of potash, silica and sulphides.
General order of solubility: Lime, magnesia, soda, potash, silica.	General order of solubility: Soda, lime, magnesia, ferric oxide, ferrous oxide and alumina.

Mineralogical Changes.

Development of oxides, carbonates, and hydrates important.	Development of oxides, carbonates, etc., subordinate.
Characteristic minerals: Quartz, kaolinite, calcite and limonite.	Characteristic minerals: Quartz, sericite, sulphides, chlorite, occasionally adularia (Oxides, carbonates, etc., accessory.)

Decomposition of all original minerals not in the list of secondary minerals.	Decomposition of all original minerals not in the list of secondary minerals. Amphiboles, pyroxenes, magnetite and biotite readily decomposed. Feldspars somewhat more persistent.
Slight net increase in mineral volume.	More or less net decrease in mineral volume, depending on the introduction of sulphides.
Molecular simplification.	Molecular simplification.

So far as thermal alterations are quantitatively known, they differ characteristically from those of weathering. These differences may be satisfactorily measured against the fairly well-known weathering processes and a better idea gained thereby of the nature of the thermal processes.

The author is indebted to C. K. Leith for suggestions and criticism.

THE COPPER DEPOSITS OF KASAAN PENINSULA, ALASKA.[1]

CHARLES W. WRIGHT.

INTRODUCTION.

The copper deposits to be considered in this article are located on Kasaan Peninsula, a promontory on the east side of Prince of Wales Island in southeastern Alaska. The Peninsula is about 18 miles long, from 3 to 6 miles wide, and embraces an area of 60 square miles between latitudes 55° 25′ and 55° 40′ and longitudes 132° 5′ and 132° 35′. It is a heavily timbered mountain range rising abruptly from salt water to dome-shaped summits reaching altitudes of 1,000 to 2,500 feet. This land mass is deeply dissected by narrow valleys or gulches on the slopes of which precipitous cliffs are sometimes prominent.

The occurrence of copper on Kasaan Peninsula was known to the Russians as early as 1865, but not until 1900 did active developments begin. The first copper was produced in 1905. It is now the principal copper-producing area in Alaska and at the close of 1907 had yielded approximately 8,000,000 pounds of this metal. The average content per ton of ore mined was 48 pounds copper, 0.035 ounces gold, and 0.27 ounces silver, or an average total value of about $10 per ton.

GEOLOGY.

The detailed geologic mapping of Kasaan Peninsula was begun during the summer of 1907 by Sidney Paige and the writer, but much still remains to be done both in the field and office before the study of the geology and ore deposits can be satisfactorily discussed. The Peninsula is of special interest

[1] Paper presented before the Geological Society of Washington. Published by permission of the Director of the U. S. Geological Survey.

for the study of igneous intrusion and metamorphism, while the ore bodies present many unique features, and the novelty of some of these geologic characteristics is the writer's excuse for the presentation of these preliminary and incomplete results.

The rocks of Kasaan Peninsula are divided into two main groups—the stratified rocks and intrusive rocks. Both sedimentary and volcanic rocks are included in the first group, and the intrusive granitic masses and dike rocks in the second group.

STRATIFIED ROCKS.

The stratified rocks, so far as known, comprise a succession of greenstone lavas and tuffs, sandstones, conglomerates, and limestones, all of which are apparently conformable and have a total thickness of several thousand feet. They occur principally on the northern portion of the Peninsula and have been generally altered both by regional and contact metamorphism. The greenstone lavas are andesitic in character, but are usually too much altered for their exact nature to be determined with precision. The greenstone tuffs contain many hornblende fragments and in places are schistose and metamorphosed to amphibolites and hornfels. The sandstones and conglomerates are composed largely of igneous material, and in places, especially near the intrusive contacts, are changed to mica schists, quartzites, and hornfels. The limestone beds are entirely recrystallized to marble and evidence of organic remains are lacking. Because of the analogy of these stratified rocks to those in adjacent areas, where paleontologic evidences are present, they are provisionally regarded as Devonian.

The stratified rocks are of interest because they enclose the ore bodies, and the occurrence and extent of the mineral deposits depends largely upon the character and composition of the strata into which the intrusive rocks have been injected.

INTRUSIVE ROCKS.

The intrusive rocks are of interest because the origin of the ore deposits has been assigned to them. It is therefore impor-

tant to know with which of the intrusives the ore bodies are most commonly found. All of the intrusive rocks are younger than the sedimentary strata which they invade. Their distribution is shown on the accompanying sketch map, Fig. 38.

The principal and oldest recognized intrusive is the granodiorite which forms the entire southern portion of the Peninsula and occupies wide areas in the central and northwestern portions.

The granodiorite intrusives vary in composition from granites to diorites and probably represent several minor periods of igneous invasion during one general period, though in some instances this difference in composition may be attributed to differentiations within the igneous magma during solidification. At the contacts of these granodiorite batholiths various phenomena are presented, such as masses of slightly altered and often sheared granodiorite surrounded by unaltered granodiorite showing sharp contacts in places, while at other points they merge gradually into one another. This suggests a peripheral solidification of the igneous batholith, fracturing of this outer portion and subsequent introduction of still molten rock into the interstices. Again we find fragments of highly metamorphosed stratified rocks forming angular inclusions in the igneous mass. Some of these fragments are recognized as such only by the presence of parallel lines of biotite flakes, the other portion of the inclusion having been dissolved by the intruding magma. A related feature is noticeable in the schist strata adjacent to the contact which show an introduction of feldspar, quartz, and other pegmatitic minerals along the bedding planes. Such instances suggest a partial replacement of the intruded beds by igneous material.

Intruding the granodiorite and adjacent metamorphic rocks pegmatite dikes occur, but are not plentiful. In composition they are closely related to the granodiorites and were probably derived from the same underlying magma.

The next period of igneous intrusion is represented by syenite masses and dikes, in places porphyritic in texture and often several hundred feet in width. These invade the stratified rocks as well as the granodiorite.

After the syenite intrusions and after the solidification of at least those portions of the intrusives now exposed, was the introduction of the ore deposits which follow the contacts of the syenite dikes or of the granodiorite masses and also occupy fissures in the adjacent rocks.

Several periods of intrusion subsequent to the ore deposition are represented by dike rocks of various composition. The first are those of diorite porphyrite, which range in width from 10 to 100 feet and are present in the mine workings intersecting the ore bodies. These are crosscut by dikes of felsite from 5 to 50 feet in width which were followed by dikes of coarse and finely-grained diabase, and these in turn by relatively small dikes of basalt. These dike rocks have no evident relation to the ore deposits and will not be considered further.

STRUCTURE.

The structure of the stratified rocks has been so greatly disturbed by the intrusive masses that no persistent lines of strike and dip can be followed, though the most prominent direction of the bedding planes is from northwest to west with a steep dip to the southwest. Two prominent jointing systems are also present on the Peninsula, the one striking N. 15° to 25° E. with a 60° to 80° dip S. W., and the other striking N. 50° to 70° W. with a steep dip to the northwest. The occurrence of these joint cracks traversing the ore bodies and country rock suggests that they were developed subsequent to the ore deposits, while the fact that most of the basalt dikes follow the prominent directions of jointing indicates that this structural feature antedates the basaltic intrusions. Fault planes and gouge seams are present in the mine workings and along these planes there have been occasional displacements of the ore deposits and the various dike rocks. The amount of such displacements, however, seldom exceeds a few meters.

ORE DEPOSITS.

The ore deposits on Kasaan Peninsula, contrary to most workable copper deposits in the states, consist of original, or primary

ores, there being little or no evidence of weathering or concentration effected by circulating waters. We therefore have only to deal with primary deposits. Three types of ore defined principally by mineral composition, may be recognized on Kasaan Peninsula, and their differences in metallic content may be attributed largely to conditions of temperature and pressure existing at the time of their deposition. The three types are as follows:

1. *Chalcopyrite-magnetite deposits associated with amphibole, epidote, garnet and orthoclase, and occurring as irregular masses along the contacts of the intrusives.*

2. *Chalcopyrite-pyrite-sphalerite deposits associated with quartz and calcite, and occupying fissures or shear zones in the greenstone tuffs.*

3. *Galena-sphalerite-chalcopyrite-tetrahedrite deposits in a quartz, calcite, barite gangue and occupying fissures in the limestone.*

As there is no evidence of more than one period of ore deposition, it is suggested that the three types of ore deposits are contemporaneous and that similar solutions introduced the ore bodies along the contacts replacing the enclosing rock and also took advantage of pre-existing fissures away from the contacts and deposited a somewhat different aggregation of minerals in them. From the intimate association of the ore deposits with the intrusives, not alone on Kasaan Peninsula but in other portions of southeastern Alaska, there seems to be no escape from the conclusion that both the ores and the intrusive rocks were derived from the same source.

The first class, or the contact metamorphic deposits, are by far the most important, both from a geological and commercial standpoint. They consist of irregular masses, from 10 to 200 feet in dimensions, composed of the minerals noted above, and occur at local points along the contact of syenite and granodiorite intrusives with limestone or greenstone tuff. Where greenstone tuff forms the adjacent rock the chalcopyrite ore is associated with hornblende, epidote, and orthoclase, and where

the limestone is the enclosing rock, the chalcopyrite is accompanied by garnet, epidote, and calcite.

In some of the mines magnetite constitutes the greater portion of the ore body forming huge deposits, and in these the chalcopyrite occurs in masses and finely disseminated grains. The entire magnetite mass may be considered the ore deposit, but only those portions containing a sufficient copper content to insure profitable extraction are mined. The distribution of the mines is indicated on the accompanying sketch map, Fig. 38.

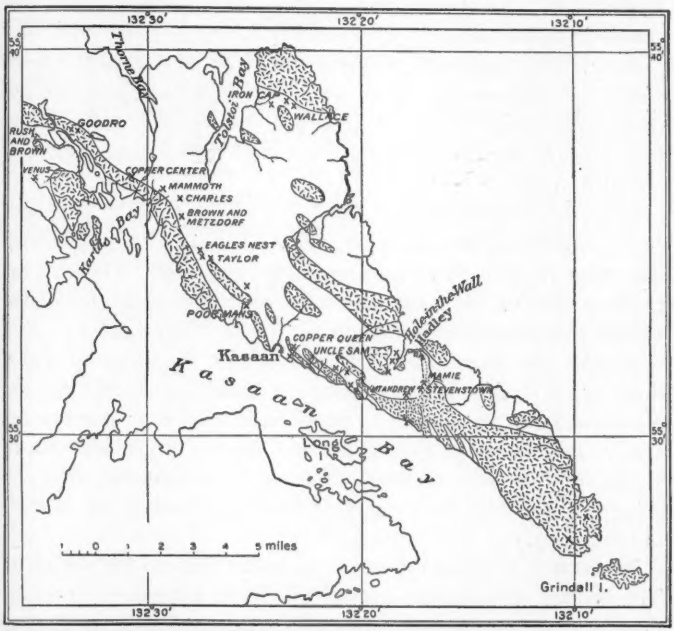

FIG. 38. Map of Kasaan Peninsula, Alaska, showing intrusive areas and positions of mines and prospects.

The properties of the three principal mines—the Mamie, Stevenstown, and Mt. Andrew—are located along the same mineral zone. This zone is about a mile and a half long and

100 to 300 feet wide and bordered by altered greenstone tuff and limestone on the hanging wall side and granodiorite on the foot-wall side. The ore bodies in the same zone closely follow the contacts of the syenite dikes, which crosscut the zone, and these dikes, as well as the intruded rocks, have been much altered by the mineral-bearing solutions. Another favorable zone for ore deposits appears to follow along the western side of the peninsula about one mile inland, beginning at a point three miles northwest of Kasaan and continuing northwestward. The Eagles Nest, Mammoth, and Copper Center prospects are included in this zone.

Ore bodies representing the second type of deposit, which consist of chalcopyrite, pyrite and some sphalerite, and occupy shear zones from 2 to 10 feet wide in a greenstone tuff, occur just north of Karta Bay at the Rush and Brown mine, and the Venus prospect.

Deposits of the third type, consisting of galena, sphalerite and chalcopyrite ores, are found occupying fissures in the limestones, and range in width from narrow seams to 10 feet. These occur to the northeast of Kasaan, usually at points away from the syenite and granodiorite contacts.

Besides the deposits belonging to one or the other of these three types, ore bodies consisting of bornite and chalcopyrite disseminated in an intrusive belt of basic diorite or pyroxenite, are being developed at the Goodro and Stevens properties. Auriferous vein deposits occupying fissures in the granodiorite are being prospected in the vicinity of Grindall, at the south end of the peninsula.

The extent of these different ore bodies varies with the type. The contact ore deposits are seldom more extensive vertically than laterally, but where the contact zone persists investigation within it will probably reveal similar masses both laterally and in depth. The copper sulphide deposits are more persistent laterally than the contact ore bodies, and will probably extend to a considerable depth. The galena vein deposits in the limestones will probably also be extensive in depth, though judging from

analogous deposits of this type, it is possible that the lead-silver ores will be replaced by copper ores in depth.

Thus, on Kasaan Peninsula we find ore deposits of many types containing various mineral associations and consisting essentially of primary ores. It therefore presents an opportunity for the study of the minerals contained in the different types of ore bodies. Such studies may possibly give a better conception of the conditions of temperature and pressure under which the ore deposits were formed, as well as to the character of the mineral-bearing solutions and may further suggest a possible way to define them more clearly, both according to their mineral composition and to the conditions under which they were deposited.

Other problems of more immediate commercial importance also remain to be solved, such as the determination of the value of the large magnetite deposits as iron ore producers and the testing of magnetic methods to locate the copper-bearing magnetite deposits in those areas covered by soil and vegetation.

EDITORIAL

The numerous inquiries which have reached the editor from the readers of ECONOMIC GEOLOGY regarding the recent changes in the editorial staff show that a few words of explanation are called for.

When the journal was projected its founders saw that two courses were open with reference to the editorial management: one was to have a practically permanent board of associate editors; the other was to elect the editorial board annually. The second plan was the one adopted, it being firmly believed by the founders that the adherence to this policy would be the more likely to secure the maintenance of an active interest in the welfare of the journal by each member of its editorial staff, tenure of office being made dependent upon present, not past, achievement and upon coöperation in the advancement of the journal toward the ideals set for it. It was further felt that even if all members of the editorial board should prove equally efficient and earnest in carrying out the work of the journal, it would nevertheless be advisable to effect some changes in membership each year, in order that the initial policy should not be forgotten and that there should be no tendency for the annual election to degenerate into a mere form for the retention in office of a virtually permanent editorial staff.

It was with this policy in mind that certain members of the editorial board recently declined to stand for reëlection. The editor takes pleasure in assuring the readers of ECONOMIC GEOLOGY that Mr. Waldemar Lindgren and Mr. Marius R. Campbell, who have been particularly helpful in placing the journal in the posi-

tion which it now holds, will continue with unabated zeal and wholly unselfish interest to work with those upon whom the editorial responsibility nominally rests. Furthermore, by the election to the staff of Mr. Horace V. Winchell, Mr. H. Foster Bain and Mr. George H. Ashley, ECONOMIC GEOLOGY gains the active support and coöperation of three men too well known to need introduction to our readers. It is our hope that few of those who may, after a year of more of service, waive formal recognition on the editorial page will cease to be an associate in fact, if not in name.

DISCUSSION

A THEORY OF ORE-DEPOSITION.

DISCUSSION OF A PAPER BY J. E. SPURR.

Sir: When Mr. Spurr's paper[1] on "A Theory of Ore-deposition" appeared I hoped that someone better qualified than I might comment on it in this journal. Since no one has done so and since criticism, when the need for it is recognized, becomes a duty, it would seem that ordinary personal considerations should be forgotten in a common concern for scientific progress. It is due, moreover, to the readers of ECONOMIC GEOLOGY that each member of its editorial staff should be particularly sensible of this duty and should not yield the assent of silence to the dubious treatment of important subjects.

Mr. Spurr begins his paper with the statement "It is the correct procedure in scientific exposition to present evidence in detail, and then the conclusions to which that evidence has led." Having announced this excellent maxim, he asks the reader's indulgence in disregarding it. If it occurred also to Mr. Spurr that the traditions of science demand some recognition of the contributions of others to his "theory" there is no indication of this in his paper. His procedure in what follows is not without precedent, but, for obvious reasons, it finds little exemplification in the literature of science. Such a plea for special indulgence inevitably suggests preference for a short and easy path to popular recognition rather than the self-forgetfulness that characterizes the earnest search for truth. This unpleasant suggestion can be wholly effaced only when the contribution offered not merely has real novelty and helpfulness but when the writer also is forced by very exceptional circumstances to use a mode of presentation so essentially unscientific.

[1] This journal, Vol. II., 1907, pp. 781–795.

No one who has followed the study of ore deposits for the last twenty years can doubt that substantial progress has been made toward an understanding of their genesis; but the discerning student cannot fail to be equally impressed by the fact that with some real gains in knowledge and with the opening of many suggestive paths of investigation there has been a tendency exhibited by some writers to confuse hypothesis with theory—speculation with induction. Much positive writing on magmatic or meteoric waters, on differentiation, and on allied subjects is, to speak plainly, mere guess-work masquerading in the garb of knowledge. Such writing is a stumbling block, particularly to young investigators, and renders difficult the practice of that restraint which, on those occasions when all available hypotheses have been tested and the evidence found inconclusive, enables an author to say: "The apparently significant facts are these; this hypothesis has most in its favor but the observations do not justify a definite conclusion."

The essential idea advanced by Mr. Spurr is that most ore deposits are extreme products of magmatic differentiation and that there is a genetic relation between what have been called petrographic or, better, petrologic provinces and what he terms metallographic provinces. This general view is certainly not new. It goes back in greater part to the days of Elie de Beaumont and has been developed in successive publications by L. de Launay[1] since 1897. The latter uses the term *metallogenetic* which most readers will probably consider better than giving an unusual meaning to *metallographic,* a word already having a narrow technical application.

De Launay considers that the initial point of departure for all metalliferous deposits is a molten metallic bath (*bain*), i. e. an "ultrabasic" magma; Spurr derives them from magmas of *intermediate* composition which he affirms, as if this were a demonstrated fact, underlie "portions at least, if not all, of the solid

[1] "Contribution a l'étude des gites métallifères," *Ann. des Mines,* new ser., Vol. 12, 1897, p. 120. "Sur les types régionaux de gîtes métallifères," *Comptes Rendus,* Vol. 130, 1900, p. 743. "Les richesses minérales de l'Afrique," Paris, 1903 (Advance abstract in *Revue Gén. d. Sci.,* Vol. XIII., 1902). "La métallogénie de l'Italie," 10th Internat. Geol. Congress, Mexico, 1906.

crust of the earth." The latter writer assumes that no differentiation of these intermediate magmas is possible "until they are subjected to unusual or catastrophic conditions" and begin to crystallize, " else " he adds in a footnote, " we should have had all magmas differentiated long geological ages ago."

All this, to say the least, is extremely hypothetical. It is by no means certain that the starting point for all magmatic differentiation and for all igneous rocks is the intermediate magma postulated by Mr. Spurr. The conclusion, which seems to be logically unavoidable, that abyssal assimilation and mixing, as well as differentiation, are factors to be reckoned with in accounting for the composition of igneous rocks and the constitution of meteorites, suggest the tenability, at least, of other hypotheses. Moreover, the exclusion from any essential participation in primary ore deposition of all waters except those of direct magmatic derivation can scarcely be effected after the summary manner of Joshua in his dealings with nature. Can the work of Gautier[1] showing that large quantities of the elements of water, and other gases, are given off when solid rocks are heated to redness, properly be ignored in an attempt to frame a general theory of ore deposition? Is there any certainty that the same fissuring or shattering that rendered the rocks pervious to ascending magmatic solutions would not also permit the deep descent of surface waters, whatever limit to such penetration may subsequently have been set by cementation and filling? Is the simple dehydration of deeply buried sediments in process of metamorphism a negligible factor in ore deposition? Has it been shown that non-magmatic water, given the requisite pressure and temperature, may not take up such constituents as to render it an efficient solvent and carrier for the metals however these may have been brought within its reach? These are a few of the questions to which a real theory of ore deposition may be expected to give satisfying answers.

Proceeding to discuss the fusion and solidification of mag-

[1] "La genèse des eaux thermales et ses rapports avec le volcanisme," *Ann. des Mines*, 6 ser., Vol. 9, 1906, pp. 316–370. Translated in this journal, Vol. I., 1906, pp. 688–697.

mas, Mr. Spurr states that "the common distinction between 'igneous' and 'aqueo-igneous' fusion (made in passing from granites to pegmatites, for example), is certainly wrong." Does this statement mean that most geologists have been in error on this point up to the present? Le Conte, fully seventeen years ago, wrote as follows: "In fact, every variety of fusion and semifusion, depending on the degree of heat and the quantity of water, may be traced, from perfect igneous fusion, through various grades of aqueo-igneous fusion, to the condition of hot mud."[1] Geikie,[2] also, shows that the recognition of this gradation goes back half a century—to Scheerer[3] in fact. Chamberlain and Salisbury write that "If the heat factor in metamorphism be sufficiently increased, aqueous solution may actually grade into magmatic solution through various degrees of softening and melting, and the cycle of changes be closed in upon itself."[4] Thus even the geologic text-books, to say nothing of individuals, appear adequately to recognize the fact supposed by Mr. Spurr to have been commonly overlooked.

In his effort to emphasize the closeness of the relation between ore deposits and magmatic processes Mr. Spurr resorts to evident exaggeration. The proposal to make *dike* and *vein* synonymous and to speak of veins generally as *intrusive* does more than "shock the conservatism of the average reader"; it shakes his faith in the sobriety of the writer. Although it may be possible to show a complete gradation between veins and dikes as classes, there is no doubt at all in the minds of most geologists that there is an essential difference between the typical or usual vein and the typical or usual dike. The proposal to obliterate the distinction implied by the use of different names, to voluntarily forego the progress of a century, and to return to the extreme view of Hutton, is probably one that Mr. Spurr would not, on reflection, adhere to. Because animal species are found here and there to merge through varieties we ought, by

[1] "Elements of Geology," 3d ed., 1891, p. 91.
[2] "Text-book of Geology," 4th ed., 1903, pp. 412–413.
[3] "Discussion sur la nature plutonique du granite et des silicates cristallins qui s'y rallient," *Bull. Soc. Géol. France*, 2d ser., Vol. IV., 1847, pp. 468–495.
[4] "Geology," Vol. I., 1904, p. 429.

this reasoning, to abandon our zoological classification. That the Germans employ one word, *Gang*, for dike and vein is no mark of their acknowledged discernment but is merely a defect in their language—in this case with a very interesting chapter of geological history behind it. The lack of a better word forces them to the frequent use of the compound *Erzgang*.[1] Such verbal poverty is no better argument for the identity of the two separate things denoted by *Gang* than is our own double use of *vein* a suggestion of the magmatic origin of the blood.

To criticise fully all the details of the derivation of ores from magmas as imagined by Mr. Spurr would take much space and is scarcely necessary. His italicised conclusions as presented at the end of his paper are as follows, the quotation being modified by the insertion of parenthetical numerals.

"Summing up, this theory proposes (1) *that metalliferous fluids, from which most ore-deposits are precipitated, are extreme differentiation phases of rock magmas;* (2) *that most ore-deposits and 'mineral veins,' as a class, represent one or the other of the extreme products of magmatic differentiation; and* (3) *that the most striking chemical differences between ore-deposits is due* (*in the more important class representing the siliceous extreme*) *to successive precipitation in theoretically vertical zones, as the fluid migrates toward the surface, and with diminishing heat achieves more and more mature crystallization. Secondarily* (4) *the differences between ore-deposits in different regions depend upon the different metallographic magma-provinces, as mentioned early in this paper."*

As already indicated, propositions (1) and (2), as hypotheses, involve nothing essentially new nor can a claim to originality based on the supposed mode or mechanism of the differentiation survive critical examination. Proposition (3), in so far as it may be true, has long received recognition in the literature of ore deposits. If it be taken to mean that a complete vertical section of any one vein would in general show more striking chemical differences than may be found in different deposits, the statement is probably incorrect. The last proposition, as we have

[1] See, for example, Beck, "Erzlagerstatten," Berlin, 1901, pp. 127 et seq.

seen, received definite formulation by de Launay prior to Mr. Spurr's first enunciation of it. De Launay, moreover, shows that this is merely one of several factors determining the regional distribution of ore types.

Finally, a suggestion concerning Mr. Spurr's use of the word *theory* may not be amiss. Let the reader compare, with reference to spirit and method, the article here discussed with the series of remarkable papers by Prof. T. C. Chamberlain beginning with the one entitled "A group of hypotheses bearing on climatic changes"[1] or with the same writer's presentation of the planetesimal hypothesis.[2] Why does the one author term his speculations a *theory* while the other, notwithstanding the rigid and laborious tests which he has applied to his own results, refers to them with the simplicity of truth as *hypotheses?*

F. L. RANSOME.

THE LOCALIZATION OF VALUES IN ORE BODIES AND THE OCCURRENCE OF SHOOTS IN METALLIFEROUS DEPOSITS.

Sir: Until the inner processes by which veins are formed, the chemistry of underground waters, the varied influences to which the forming or already formed minerals are subjected prior to the time when they come under our observation are studied, in short until we understand the *rationale* of vein formation and subsequent alteration the last word on the occurrence of ore shoots will remain unwritten.

The fact of their occurrence in nearly every form of ore deposit, large or small, of whatever origin, is so well understood that our wonder is aroused whenever for a considerable distance on strike or dip they appear to be wanting. To attempt an explanation of their formation in all cases seems like undertaking a "Theory of the Earth."

It has seemed to me however that ore shoots fall easily into two general classes as regards the date of their origin: (1) those

[1] *Journal of Geology*, Vol. V., 1897, pp. 653–683.

[2] Chamberlin and Salisbury's "Geology," Vol. II., 1906, pp. 38–98.

which were formed in whole or in part during the original deposition of the vein as a whole; and (2) those which were produced by later influences of one kind or another. The former may be called *paragenetic* and the latter *postgenetic*. Under the diverse conditions of ore formation it is seldom to be expected that the values, thickness and mineralization of any vein should have been uniform and alike over any great distance. But, even if such were the case, it is hardly conceivable that the dimension, character and tenor of ore veins should have remained unchanged through all the subsequent ages of chemical and dynamic activity. Solutions have come and gone; water level has been frequently changed; temperatures have varied; density has fluctuated; strains have begun and been relieved; shearing and faulting have crushed the old minerals and opened cavities which have been filled by new ones; until what may have been originally a simple homogeneous mass has become impoverished here and enriched there; here distended and there enlarged and as full of variety as a vaudeville performance.

Paragenetic Shoots, or those occurring in the vein from the time of its original formation may frequently be distinguished by their form. Those shoots "due to available open space" and called "shoots of occurrence" by Irving are examples. The vein walls approach or retreat from each other, due to inequalities in rock structure or movement after fissuring; and the resultant form of the filling is lenticular or elongated. When such an enlargement coincides with a flattening of dip there is frequently a very decided enrichment, but without any change in the character of the ore minerals.

Deposits of substitution and impregnation also often exhibit paragenetic ore shoots due to the differences in physical condition or variation in solubility of portions of the mineralized rock. Such shoots are much more irregular in outline than those just mentioned.

Shoots formed at the intersection of joints or of fault fissures are often paragenetic; but may be also postgenetic, for at least that portion of the mineralization which may have been introduced into the older veins as a result of later movements.

Postgenetic Ore Shoots are of two kinds: (*a*) those produced in the veins by internal movements, cross fractures or physical agencies by reason of which the vein contents have been mechanically or chemically rearranged since their first deposition, and (*b*) those formed by secondary action through surface waters admitted in greater or less quantity to the vein as controlled and directed by surface conditions, as well as by the attitude and composition of the vein itself.

Under the first class we have those shoots which are obviously associated with faults; and in many regions these are by far the most abundant and commercially important. When, as is often the case, we have secondarily enriched ore shoots adding to the riches already contained in postgenetic ore shoots of class (*a*) and these two increasing the mineralization of paragenetic shoots we have bonanzas which make famous camps like the Comstock, Aspen and Butte.

Postgenetic ore shoots of class (*b*) are far more numerous than is generally supposed. In the case of the secondary copper sulphides they are easily recognized and correctly diagnosed. But, more difficulty is experienced with ores of gold, silver and lead; and I am convinced that the correct interpretation is not usually placed upon these latter. They may extend downward for considerable depth; but they will sooner or later taper off in both size and grade of ore; and in my experience the tapering process begins sooner rather than later, even in our most sensationally rich mining districts. In fact, a longitudinal section of the richer ore in many gold veins looks like a cross-cut saw with an occasional tooth elongated here and there to a lower level than the average. But the teeth are there and on the under side; and the extensive bodies of bonanza ore are above, instead of extending downward indefinitely with the lower grade portion of the vein.

It appears therefore that the whole history of a vein from its incipient stages to its condition today, its environment, its interrupted periods of growth, its internal changes and its character as a drain pipe for the rains of every season all tend to the development of inequalities in its make-up. And all the agencies

that operate upon it after its first formative period tend to accentuate its peculiarities, emphasize its idiosyncrasies and separate the valuable from the worthless, thus creating ore shoots, without which few mines would be able to pay dividends.

HORACE V. WINCHELL.

MINERAL RESOURCES OF CHINA.

DISCUSSION OF PAPER BY BAILEY WILLIS.

Sir: Information about Chinese ore resources is so meagre that I may be excused for adding a mite to the interesting notes contributed to ECONOMIC GEOLOGY by Mr. Bailey Willis. The southeastern part of China, in the Canton neighborhood, seems to have been passed by in the itineraries of most travellers, but a hasty trip along the East River some years ago led me to think it one of the most interesting parts of the country in a technical sense. It may be that one of the most important iron districts of the empire and one comparable to the great localities of our country is to be found there.

The Tsi Kiang River on which Canton is situated has an east and west course and, lying entirely west of the city, is locally known as the West River. The Pei, or North River, flows into it just west of the city and the East River flows into the arm of the sea, which is the "Canton River" known to foreigners a little below the city.

Taking boat at Canton I went up the East River to the political districts of Lien P'ing and Chung Ning. Lead, silver, manganese, tin and coal were reported there but I found the appearances too poor for exploitation, but passed some exposures of iron ore that were very striking.

Ninety-five miles from Canton a branch stream called San Fung Kong enters the East River from the west. After travelling forty miles by boat on this stream I reached Chu Hang from which place a trip of ten miles over the rough hills called K'o Lo Shan lying north of the river in Lien P'ing district took me to a series of important outcrops of magnetite. One of these was

very large and had been quarried out for a height of 30 to 40 feet with a removal of perhaps 5,000 tons of ore. I was told that mining had gone on here for one hundred and fifty years, but that statement is a common one in Chinese mining districts. There were several large buildings at the mine (but no furnaces) and from their good state of preservation I judged that the mining of this ore had been done in imitation of the "foreign way" and was not more than thirty years old. Operations ceased when foreign scrap iron began to be imported in large quantities, reaching 500,000 tons in one year when I noticed the statistics. This was a massive outcrop, 30-40 feet thick, as I remember it and is called Kang Shan Tou. Two other similar though smaller exposures were passed on the road and a fourth was seen on a more distant hill. Fragments of magnetite were noticed in the soil for a distance of two or three miles and the natives said the ore ground extended for twenty li (*i. e.,* six miles). The ore appeared to be soft for magnetite and free from macroscopic impurities. There is a possibility of developing here an extensive iron region with large bodies of rich ore which may be comparable in resources to such American localities as Lake Champlain, the Gogebic, etc. Further down the river between Ui Lung and Sik Cheung I had passed a small furnace, eight feet high, smelting a mixture of limonite and magnetite and my impression is that this ore did not come from any locality that I saw.

There are small veins of bituminous coal in these districts and the coal at Chang Lok, 90–100 miles east, is reported to be more important. The Chinese use it for fuel, which is rather a guarantee of practicability in that climate.

Before reaching the above locality I had passed outcrops of specular hematite lying east of the river and 30 to 40 li (10–15 miles) from Fu Chuk Kai, a town situated at the junction of a small stream and the East River about 80 miles from Canton. The exposures are near I Yung, a town well known locally though not on any map that I have seen. The particular localities are on the road between I Yung and Chang Pu, in Yung On district, at a place called Wang Tung Hao and a farm named

Ma Tou Shan (Horse Head Mountain) in the same valley as Chang Pu. The quality of the ore seemed to be excellent, but the outcrops were not very large, though numerous.

The Chinese are eager to see their rails made from native ores and I do not know a better place for beginning the industry than here. Coal could be brought by sea from Tonkin and railroads to coal and to tide water made from the native product. In addition to the drawbacks to Chinese mining which Mr. Willis gives must be mentioned the propensity of that people to demand the latest improvements in any art rather than those which are within their means and powers of control. They have found it difficult to get ores suitable for steel making, but if they would give up the idea of making Bessemer steel and content themselves with *iron* made by a mechanical puddler they would produce from mines known to be available, rails that would be superior to anything the English and Americans had in the beginning of their industrial and railroad development and serviceable under Chinese conditions for many years.

Besides the two ores mentioned I saw limonite at a small furnace which was in blast, but did not run across any mine of this ore. It may seem strange that the Chinese should neglect a rich and easily reducible ore like hematite for an ore of lower grade, but I presume there is phosphorus enough in the limonite to make a thin-running metal such as is needed for the manufacture of the large rice pans which are often made of remarkable thinness.

These localities are not to be found on any of the ordinary maps, but a Swiss missionary, the Rev. J. G. Loercher, published in 1879 a fine map of Canton Province, in great detail, on the scale of 1:586,000.

Another locality, of geologic interest only, is at T'ou K'ou in Mongolia, 2,000 miles or more north of Canton. T'ou K'ou is 80 or 100 miles north of the Great Wall. Here are several outcrops of titaniferous magnetite of great size. The mineral contains up to 11.5 per cent. TiO_2, 8–10 per cent. SiO_2, in the form of a green aluminous mineral and 54 per cent. Fe. Five exposures, one very large, were seen.

JOHN A. CHURCH.

PEAT, ITS ORIGIN, USES AND DISTRIBUTION IN MICHIGAN.

DISCUSSION OF REVIEW BY M. R. CAMPBELL.

Sir: I appreciate very much the review of Professor Davis's peat report (Volume III, page 248). The one point of criticism is one for which I am *personally* responsible, and for which the *author* is not. It is that part of the culture is printed in a weak color. I do not find it myself "utterly unreadable," but I am free to confess that it is only with very great difficulty readable in many parts. The criticism brings up a fundamental question concerning which I should like the judgment of any who would care to write either to me or to you.

When I first worked for the United States Survey with Mr. Keith in Tennessee we had some very pretty looking contour maps, but we found that there was great difficulty in finding a fixed point upon them by which to locate ourselves and from which to locate accurately any outcrop which we wished to place upon the map. We could by the contours get it say within a half mile or so, provided the contours were not that much wrong, which occasionally they were. It must be remembered that this was twenty years ago and does not apply to the accuracy of the contour maps now issued by the United States Survey. At the same time a contour is rarely identifiable in the field with the accuracy of a cross roads or section corner. Now geological maps have two purposes. In the class room they are meant to show general relations and extreme accuracy or the ability to locate a definite point is not of importance. But if one is going to use these in the field, or to determine what formation a well for oil at a given railroad station will strike, at what depths, etc., then a very different degree of accuracy is required. For such purposes it is of great convenience to have railroads located upon the map, even though in an obscure color. If one is particularly interested in a special railroad he can easily ink that in and make it as conspicuous as he desires, in five

minutes with the faint underprint, where it might take hours to do it with equal accuracy without this.

Now it is a question if it is not worth while in many cases to use an underprint base which is *not* plain, even obscure in places, but which does not interfere with the bringing out of the main geological features and from which with a little study, possibly at times with the help of a reading glass, the exact location of many features which have no geological bearing, like railroads, may be obtained for practical use when needed. I am not sure that our peat map of the Lower Peninsula is a successful experiment along that line, but I am inclined to think it is. I should like to have discussed the importance of indicating in some way upon a map a lot of features which have not geological bearing but which simply serve to locate oneself or one's property upon the map.

ALFRED C. LANE.

REVIEWS

Mining, Mineral and Geological Law. By CHARLES H. SHAMEL. Pp. 627. Hill Publishing Co., New York, 1907.

The author of this volume has set himself the task of combining in one volume a brief geological treatise for lawyers and a digest of mining law for mining men. His avowed object is "to include all those subjects that relate to goelogic features—those that concern topics on which geologists and mining engineers may be called upon to give expert testimony—and those that concern the physical conditions of mining as contradistinguished from the law that affects mining in common with other industrial undertakings." He admits that "the various features and the meaning of the rather vague provisions of the national mining laws have caused the mining profession much anxiety, and have evoked much discussion;" but thinks that "nearly all of these uncertainties have now been cleared up by the decision of the Supreme Court of the United States." With a suitable digest, therefore, it may be possible for a mining man to form some idea of his rights to mine a certain vein, even though the patent which gave him title and the law under which said patent was issued is vague and indefinite.

He does not "hope or wish to make every geologist or mining man 'his own lawyer'"; but his belief is that "such a treatise as the present one will often help to avoid that particularly fierce litigation which so often brings undeserved disaster on meritorious mining enterprises." In other words, he blames ignorance of the law rather than the law itself and the avariciousness and stubbornness of human nature for the ruinous litigation which has prevailed for years in many western mining camps. With this opinion the reviewer is not in accord. It is his experience to find both parties to these contests well versed in the law and decisions relative to mining, and well provided with legal talent. And since human nature is and has been much the same in all countries since the dawn of history, it seems to us inherently and fundamentally the fault of the mining law of the United States that such troubles constantly arise in mining camps. In the Lake Superior region where the mineral land laws do not apply, mining litigation is of almost unknown occurrence. And in case of trespass by one mining company upon the property of another, the matter is simple and easy of

settlement without resort to litigation. In the western states, however, almost every important mining camp has been afflicted by long-continued, and as our author says, often ruinous litigation which has not infrequently led to bloodshed and loss of life. Recognizing the liability of such complications the mine owners of some districts, such as Bisbee for example, have entered into a mutual agreement establishing vertical boundaries to their properties. These wise corporations, by radically modifying the provisions of their patents from the United States, have saved themselves from expense and annoyance that would otherwise have been inevitable. That the present mining laws are a fruitful source of revenue for mining attorneys and expert witnesses is not only readily granted, but has been exemplified in the personal experience of the reviewer during a professional career of about twenty years.

But how any one actually familiar with conditions in the various portions of this country, Canada and Mexico, can persuade himself that (in the interest of the mine) the present system should be retained a moment longer than necessary, is beyond comprehension. Not only does it lead to endless law-suits, but new questions are constantly arising and no one can tell how the courts will hold in several situations of common occurrence, as yet undecided. The case of the St. Louis Company *vs.* the Montana Mining Company, Ltd., is an example of the possibilities under our present system. This case has been in the courts for fifteen years; has been to the Supreme Court of the United States six times, and is now about to be started all over again upon the third amended and supplemental complaint. Fifteen years more may elapse before its conclusion. Lawyers and witnesses have passed away; the mine is practically worked out, and yet the fight continues, to the expense and annoyance of both parties to the suit, and certainly working an injustice to one or the other of them. Under the mining laws of Ontario or British Columbia such a condition were impossible.

At present, however, we must take the law as it stands; and review Dr. Shamel's method of discussing it, and not alone his strong approval of it.

After mentioning the origin of the present law, he proceeds to furnish a few definitions followed by some delightfully readable chapters on "legal geology." Among his definitions we note that *minerals* should hardly be restricted to those "found in nature," and that the term *drift* is not generally applied to "a nearly horizontal excavation extending from the shaft to the mineral." For such an opening the term *cross-cut* is used, while a drift is commonly in, or alongside of, the vein parallel to its strike.

A *winze* also is an underground shaft; but does not necessarily pass from one level to another.

Interesting also is the discussion of the origin of various kinds of title to natural property and objects, such as minerals, oil, gas, tailings, and meteorites. Precedent in the latter instance is found in a case in which the reviewer was defendant; and in this instance we are able to vouch for the correctness of the author's statement that "meteorites vest in the owner of the land on which they fall," becoming real estate rather than personal property.

Oil, gas and coal are minerals under the law, and so is rock used for building material. "Other minerals which have been held by the decisions of the Land Department to come within the United States laws relating to mineral land, are: albertite, gilsonite, alum, amygdaloidal bands, agate, fahl-bands, garnet, graphite, lithographic stone, mica, opal, slate, tin, turquoise, amber and wax."

The fifth chapter is devoted to an excellent review of geological theories, paying particular attention to the origin and nature of ore deposits. The author is familiar with the literature of geology and discusses the various theories since the time of Werner with discrimination and due appreciation of their respective merit. Indeed, this treatise on law contains a better balanced and more accurate and scientific presentation of those certain geological theories which it discusses, than many works on geology.

The origin and development of our present mining regulations are discussed; and the pleasing as well as suggestive information is afforded that Germany at one time had provisions for the extralateral pursuit of ores; but that they have been superseded by laws "under which mining rights are bounded in depth by vertical planes."

After describing the proper method of procedure for locating and acquiring mineral lands, the author comes to the scientific definition of a vein and the description and illustration of various kinds of veins. His definition of a fissure vein as "a cleft or crack in the rock material," etc., is hardly on a par with his customary clearness and accuracy. To us a fissure vein is not a cleft or crack, but is the material occupying such an opening. And we would suggest as a better definition that a fissure vein is a tabular mass of minerals which have been deposited from aqueous, gaseous or vaporous solution in a crack or shear zone in the rocks of the earth's crust. His general definition of a vein is better; (p. 163) "a body of mineral different from the containing walls, more or less sheet-like in form and contained within the rock-mass of the earth's crust."

Many of the illustrations in this chapter are excellent, while some of them, as for instance that on page 151, are obscure. This one in particular has been reproduced so often since it was first published by Von

Weissenbach in 1836, that it is almost unrecognizable. Its legend, as also that for the cut on page 133, is wanting. The illustration on page 231 is also from Weissenbach.

The best legal definition of a vein is that it is a body of mineral or mineral-bearing rock within defined boundaries in the mass of the mountain, substantially as given by Judge Hallett of Colorado.

After a discussion of the various decisions, the author states that "the term *vein* or *lode* as used in the United States statutes, includes practically all mineral deposits found in 'rock in place.'"

The apex of a vein is "the edge or termination of the vein which comes nearest to the surface of the earth, forming an outcrop, or which comes nearest to the surface when the vein terminates before it reaches the surface." Thus it is not a point, "but often a line of great length."

Coming to that provision of the law which has caused most of the trouble, the author reviews at length the different cases wherein controversy has arisen, and gives rules based upon the decisions. Some of these rules are not exactly stated; and in some decisions, points of importance seem to be overlooked. Upon page 207 for instance, is this rule: "The law is well settled, that, when the vein crosses both side lines instead of the end lines, the original side lines become end lines, and that between vertical planes passing through these new end lines the vein may be pursued on its dip to any distance whatever." This is a very important rule but is true only when the original side lines are substantially parallel.

One important point in the San Carlos and Viola case, illustrated on page 227, which is apparently overlooked, is that while in case of divided apex, the senior location takes all of the vein within the planes of its end lines, the junior location has also extralateral rights to the full vein beyond the limits of the rights of the older claim. The Stemwinder and Sierra Nevada cases are also incompletely or loosely cited.

The argument of the author in favor of the retention of the present mining law, is given substantially as it appeared in ECONOMIC GEOLOGY, Vol. II, p. 62. Then follow chapters on placers, water rights, the use of geological features in marking boundaries, and in miscellaneous ways. The latter half of the volume is taken up with forms, local statutes, land office rules and decisions.

Upon the whole this volume is one that should be useful to miners, geologists, and lawyers. It presents in concise form and in a novel manner, just the information that men of these occupations need to save them from litigation, or to guide them when it has arisen. The reviewer has made frequent use of it and already looks upon it as an almost indispensable part of his equipment, whether at home or "on the road."

HORACE V. WINCHELL.

Tests for Ores, Minerals and Metals of Commercial Value. By F. List McMechen, Mining Engineer. Pp. xvi + 151. D. Van Nostrand Co., New York, 1907.

This little volume is offered as a field reference book and an aid to the mineral seeker and prospector, and to others who are interested in ores and minerals and have not had the time to consult the larger works on geology and mineralogy.

It is difficult to imagine in what way the book could be of use to anyone with the knowledge of these subjects that seems to be necessary in order to recognize the truths it contains. The author announces in the preface that he has endeavored to be as brief and concise as is consistent with clearness. In this he may have been successful, but he seems to have overlooked the all-important necessity of being accurate, and although the claim is made that the works of the best modern authorities have been compared in compiling the book, yet errors of a most painful nature have crept into it, and unfortunately, they came not singly.

The very first sentence is a shock to the reader's confidence. It is written "rocks are formed in two ways—by water or by fire—in either case heavy pressure plays a great part." In the first page and a half we read that chalk is "a soft, white rock composed of calcium and magnesia, formed of the crumbled remains of marine fossils," that "a clay containing lime is unfit for brick," and that coral is "a calcareous (calcium or lime) rock formed of the remains of coral insects." "Corals and other marine insects" are mentioned a number of times in the descriptions of limestones. On the third page the author undertakes to describe greensand and considers it consistent with clearness, not to mention accuracy, to limit his remarks to the single sentence, "green sand, or green earth, is a foliated granular or earthy sandstone." Within the next few pages "metamorphized" is substituted for the word "metamorphosed" no less than six times.

Later in the book there is given a list of "minerals commonly entering into the composition of igneous rocks." There are described in this list only twenty-five minerals. Four of these are plagioclases, not distinguished by their descriptions, and anorthite is omitted. Strange to say asbestos and beryl, and strangest of all ultramarine, are described, while garnet, hypersthene and titanite are omitted. Nephelite is stated to be one of the scapolite group. This is not only altogether incorrect, but it is an inconsistency, since except in the cases of the feldspars and micas, none of the other minerals are referred to groups.

The lack of good discrimination in the collection of material, and

the looseness with which it seems to have been handled is altogether too apparent to escape the notice of even a casual reader.

A. J. ELLIS.

A Pocket Handbook of Minerals. BY G. M. BUTLER, E.M. Pp. xx + 298, Figs. 87; four folding plates. New York, Jno. Wiley & Sons, 1908.

No stronger contrast between two volumes intended for the same use could be furnished than is presented by this attractive little book and that referred to in the preceding notice. Professor Butler, however, has confined his attention solely to minerals. These he describes in brief form, illustrating where necessary by simple cuts and half-tones. Their most important diagnostic features are printed in heavy type and abundant cross references are given under each species. The arrangement is approximately that of Dana.

The volume concludes with "lists" of the commercially valuable ores, of the prices of gem materials, and of the quoted values of crude minerals. A glossary contains brief but accurate definitions of terms used in the body of the book. Finally a series of folding sheets is furnished on which are indicated the principal physical properties of each of the minerals discussed. These are expected to serve as a key to aid in the determination of the species.

So far as can be judged by a cursory examination of its contents, the book is accurate and simple. It will serve as an excellent pocket companion for the student or mineralogical rambler, but will probably be of little value to the average prospector because of its technical style.

The volume is beautifully gotten up. Its typography is clear and handsome and its binding strong and tasteful. Its size, 7 inches by 5 and one-half inches, is just about right for a coat pocket.

W. S. BAYLEY.

The Geology of the Coromandel Subdivision, Hauraki, Auckland. BY COLIN FRASER, assisted by JAMES HENRY ADAMS. New Zealand Geological Survey, Bulletin No. 4 (New Series), Wellington, 1907. Pp. 154, 11 maps, 2 sheets of sections and 33 half-tone plates.

The Hauraki mining district in the northern part of the north island of New Zealand contains three principal mining centers—Coromandel, Thames and Waihi. It is with the first or northernmost of these, corresponding approximately to the northern half of the Colville Peninsula, that this report deals. The small town of Coromandel is situated on the west side of the peninsula, almost due east of Auckland and on the opposite side of Hauraki Gulf.

The oldest rocks in the district are argillites and graywackes divided into the Tokatea Hill series, supposed to be the older and containing interbedded volcanic rocks, and the Moehau series which contains no contemporaneous igneous rocks. The rocks of both series are overlain, probably unconformably, by the Manaia Hill series consisting of conglomerates, grits, graywackes and argillites. The Manaia Hill series is assigned to the Jurassic and the two older series are designated merely as pre-Jurassic. The three together constitute the folded and eroded pre-Tertiary basement of the Colville Peninsula.

Resting upon these older rocks with marked unconformity are coal-bearing Eocene beds called the Torehine series. After a period of deformation and erosion which left only residual patches of these Eocene rocks, volcanic eruptions began, supposedly in late Eocene time, which continued through the Miocene and Pliocene. The thick accumulation of Tertiary volcanic rocks is divided into three groups corresponding to successive eruptive periods. Those of the first period (Eocene?) consist of andesitic and dacitic tuffs, breccias and lava-flows with some rhyolitic tuffs. Those of the second period (Miocene) consist of andesitic and dacitic tuffs, breccias and lava-flows. The rocks of the third period (Pliocene) are rhyolitic tuffs, breccias and lava-flows. The lavas of the three periods are described in considerable petrographic detail and their chemical character is shown by numerous analyses. Their texture is illustrated by many photomicrographs, the half-tone reproduction of which is not in all cases satisfactory. The usefulness of these plates would be much increased were each accompanied by explanatory notes.

From the description and structure sections it appears that the volcanic series is of great but undetermined thickness and that it has been subjected to moderate deformation. It is evident that much remains to be learned regarding the structural geology of the region.

Mining near Coromandel began about 1852 and appears to have been fairly active until 1898, since when production has declined. The author of the report states that owing to the temporary cessation of mining practically no study could be made by him of underground workings. The total production of gold to the end of 1906 is estimated at £1,743,790 —not a large sum for so old a field.

The principal veins carry gold and silver, the latter being sufficiently abundant to form the natural alloy known as electrum. This alloy is associated with pyrite in a quartz gangue. Calcite is abundant in some veins and galena and chalcopyrite occur in certain low grade ores. Other minerals recorded from various mines are argentite, pyrargyrite (proustite ?), cinnabar, marcasite, arsenopyrite, bornite, sphalerite, native arsenic, and stibnite. The veins generally range from two inches

to ten inches in width and as a rule show crustified and vuggy structures, although conspicuous banding is rare. The gold appears to be very irregularly distributed in these narrow veins and it is stated that the greater part of the output has come from very rich pockets or bonanzas. Such evidently are not the conditions most favorable to deep and extensive mining operations.

The veins traverse all the formations up to and including the volcanic rocks of the second period. They occur chiefly in a belt stretching for about twelve miles east-northeast from Coromandel. The veins are generally short and exhibit great variety of trend. One of the principal groups, that of the Hauraki mine just west of Coromandel, shows a complex of intersecting and branching fissures of which the plan recalls that of the Battle Mountain vein group at Cripple Creek. The ore shoots are said to occur mainly at intersections. The Hauraki group of veins is credited with a total production of £400,000 from workings less than 400 feet deep.

The andesites and dacites in the vicinity of the veins have undergone what is described as propylitic alteration. At a depth of about 400 feet, however, a depth which marks the lower limit of the known bonanza ores, the altered rock is said to be more chloritic and less calcitic. One shaft, 1,000 feet deep, has shown that 900 feet below the surface is the top of a second zone of propylitic rock. Whether this corresponds to a second bonanza zone has not yet been shown. It is unfortunate that Messrs. Fraser and Adams were not able to gain access to the mines and to study more thoroughly the economic problems suggested by their investigation. Probably most readers, like the reviewer, will wish to know more about those horizontal zones of alteration and their relation to mineralization and antecedent structure.

Two periods of mineralization are recognized. The veins formed during the earlier one do not extend into the second group of volcanic rocks (Beeson's Island series). Those of the later period, on the other hand, cut these volcanics.

The report is accompanied by a geological map (without contours) in three sheets, with the scale shown in chains. This unit is so little employed in modern geological cartography that most readers, accustomed to scales of miles and kilometers, will have to search their memories of school days in order to discover that the scale here used is one mile to the inch in disguise. Anyone with whom the muddle of English measures is not a cherished birthright may resort to dividers and reference books—and serves him right.

F. L. RANSOME.

Importance of Uniform and Systematic Coal-Mine Sampling. By J. S. Burrows. U. S. Geol. Surv., Bull. 316. Pp. 486–517.

In this paper Mr. Burrows analyzes a large amount of data recently collected by the St. Louis Fuel Testing Plant and advances to further precision certain determinations made by Mr. Campbell.[1] After discussing in some detail the methods of sampling coal beds he takes up the determination of certain correction factors or coefficients whereby it is proposed to deduce the analysis of the coal as delivered from the analysis of the coal in the mine. These coefficients he gives as below, indicating with a question mark those which he considers as yet insufficiently supported.

Coefficients for Correcting Mine Samples Approximately to Commercial Coal.

Moisture.	
For run of mine coal with less than 5 per cent. in mine sample.	1.19
For run of mine coal with more than 5 per cent. in mine sample.	.93
For screened coal (lump, egg, nut, etc.)	.97
For slack coal	1.30(?)
Sulphur.	
For run of mine coal with less than 3 per cent. in mine sample.	1.07
For run of mine coal with more than 3 per cent. in mine sample.	1.06
For screened coal (lump, egg, nut, etc.)	1.10
For slack coal	.90(?)
Ash.	
For run of mine coal with less than 7 per cent. in mine sample.	1.62
For run of mine coal with more than 7 per cent. in mine sample.	1.28
For screened coal	1.37
For slack coal	1.86

Following this he gives the results of a very interesting series of studies of mine sampling carried out in a Williamson county, Illinois, mine. These were directed toward determining: first the variation between samples taken by identical methods at distances 500 feet apart, second the effect of shipment of samples in sealed cans versus canvas bags, third the variation due to the size of the sample cut and fourth the effect of crushing the sample to various sizes before shipment. The results indicate the general reliability of the method adopted, the importance of using sealed cans in shipping samples, the importance of taking large samples and the unimportance of crushing the samples before shipment, finer than to one-half inch. For further consideration a portion of the results of the tests are quoted below. To the figures as given are added the percentage of ash in the dry coal and in several cases the percentage of moisture on a no-ash basis.

[1] Economic Geology, Vol. II., No. 1, p. 48.

Sample No.	Shipment.	Ash rep't.	Dry Ash.	Moist rept.	Moist, no ash.
3629	can	7.62	8.37	8.72	
3628	"	8.45	9.26	8.80	
3630	"	8.43	9.26	9.02	
3631	"	8.40	9.19	8.63	
3632	"	8.03	8.81	8.88	
3633	"	8.05	9.94	9.00	9.78
3677	sack	8.43	9.07	6.97	7.61
3634	can	9.21	10.14	8.85	9.74
3635	"	8.60	9.48	9.29	10.16
3675	sack	8.87	9.54	7.08	7.76
3676	"	8.92	9.61	7.13	7.82
3638	can	9.70	10.66	9.00	10.69
3670	sack	9.34	10.04	6.99	7.71
3637	can	9.68	10.62	8.90	9.85
3671	sack	9.48	10.17	6.76	7.50
3789	car	9.98	10.82	7.78	8.64

Assuming that the coal itself is the same in the various samples the two variables are moisture and ash. It is impossible to make direct comparisons when there are two variables, therefore it is important to make ash comparisons on the basis of dry coal. On this basis it is evident that the variation is ash content in the mine samples while nominally 1.86 per cent. between highest and lowest was actually 2.29 per cent. The average dry ash of all mine samples was 9.67 per cent. The maximum minus variation was 1.30 per cent. and the maximum plus, .99 per cent. As compared with the car sample the average dry ash of the mine samples was .99 per cent. low. If we compare the average dry ash calculated from the analyses of the first five samples, 8.98 per cent., with the average based on the two composites of the same samples, 9.00 per cent., the result indicates clearly that compositing is an accurate method of getting average ash sample. If we take all the general samples cut at point D (Nos. 3634, 3635, 3675, 3676, 3638, 3670, 3671), together with the composites of the others (3633, 3677) we find a maximum dry ash variation from the average of only .84+ to .88— per cent. Apparently then the ash variation in the samples is not due to methods but reflects actual variation in coal bed. These various conclusions give us confidence in this method of getting at the ash in the coal. It remains to inquire how accurate is the proposed coefficient for converting a mine-determined ash to a commercial ash.

It should be remembered that in nearly all cases the comparison made by Mr. Burrows is based on a single car of coal. For comparison are given below the actual deliveries in Chicago for one month, calculated to a dry ash basis, of coal from this same region, and also for coal of the same general type but not from the same district.

Williamson County Coal, Screenings, dry ash.	Eastern Illinois Coal, Screened, dry ash.
17.4	13.3
15.0	13.4
15.3	12.4
15.5	14.1
20.4	14.7
19.0	15.1
18.8	16.8
	12.0
	13.8

The first column gives the dry ash of screenings, a class of coal Mr. Burrows has not specifically discussed but which corresponds to mine run except for the absence of lumps. The second is screened coal and strictly comparable to one of the groups discussed by him. In the first case it is seen that there was an ash variation of 5.4 per cent. and in the second of 4.8 per cent. If the disturbing effect of the moisture had not been calculated out the differences would have been even greater. As it is they are much greater than the factor which it is proposed to use. Using for convenience and as the nearest available one the mine run correction factor and applying it to the dry ash, the ash content in the first case should have been about 12.54 per cent. Actually it varied from 3.46 to 7.86 per cent. above that. In the second case the calculated percentage is 10.06 and the excess ranges from 1.94 to 5.74 per cent. above. Apparently the correction factors proposed for ash are not likely to be of very great use in their present form. It is entirely possible that factors might be determined for individual districts and particular sizes and grades of coal if based on a sufficient number of car analyses. For example, at one of the mines in the Danville, Illinois, fields a mine sample, taken substantially according to the methods discussed by Mr. Burrows, gave 9.13 per cent. dry ash. The average dry ash in eight cars of lump coal mined the same day was 11.71 per cent. and in seventeen cars of screenings was 13.75 per cent., giving factors of 2.58 and 4.52 respectively.

It is clear also from a study of Mr. Burrows's tables (p. 496) that a coal such as is mined at Springfield, Illinois, and in which the ash is finely distributed will give a lower grade lump coal than one in which the ash is largely segregated in definite bands as in the Carterville district; while there will not be the same difference as regards screenings. Apparently the differences in the coal itself as well as in the conditions under which it is mined, are too great to give much importance to such general correction factors.

With regard to the sulphur content the conclusions to be drawn are

less clear. Mr. Burrows shows in the case of coals containing less than 3 per cent. of sulphur that in sixteen cases there is an excess of .26 per cent. in the mine samples and in 41 cases an excess of .23 in the car samples. In coals carrying more than 3 per cent. the corresponding figures are .26 per cent. average excess in nine mine samples and .47 per cent. in sixteen car samples. The amounts are all small but when the excess is on one side approximately one third of the time and on the other the remaining two-thirds it is a little difficult to see the justification in applying a correction factor which one-third of the time will, if these figures are correct, accentuate the trouble. Further investigation is evidently needed and smaller groups must be considered.

In the case of moisture there are still further difficulties. Moisture varies in the coal in the mine. It varies in commercial coal also as a result of a large number of conditions such as size of the coal, season of shipment, time on the road, etc. It furthermore has an apparent but not real variation in analyses as usually stated, due to the presence of variable amounts of ash and the entering of the latter into percentage calculations. To illustrate this a few of the coals analyzed have been recalculated to a no-ash basis. In coals running so nearly the same in true ash as the samples here studied this matter is not of large importance but in commercial coals it may well be of considerable importance.

Moisture in commercial coal is ordinarily a dilutant only and should be determined merely to discover how much actual coal is delivered. It is of the same importance as the weight of the wagon is. Ash on the other hand involves extra expense in handling and often conditions the efficiency of the burning. If one examine Mr. Burrows's tables of moisture excesses he will find as in the case of sulphur that the excess is not consistently on one side, though here the difference between high moisture and low moisture coals is evidently significant. If, however, one were buying steadily of Illinois 11 B, 26, 27, or 34 B, and applying the correction factor to the mine sample instead of determining the moisture in the coal as delivered, he would be cheerfully paying for excess water. This, apparently, would be true in 25 per cent. of the deliveries of the high moisture coal. Here again it is apparently desirable that the large groups be broken up into smaller units.

It is to be regretted that the B. t. u. values of the coals, together with the period intervening between sampling and analysis, were not also studied. It is now known that there may be a variation of as much as 5 per cent. in the heating value of the same coal, arising from deterioration of the sample and not shown by loss of weight as ordinarily determined. The sealed iron cans protect against moisture losses

and are to that extent an improvement on the old method of shipping in canvas bags but they do not protect against the loss of volatile of high heating value which escapes when the can is opened for analysis. There is still a question whether, if we are to work toward commercial coals from mine samples, canvas bag samples may not, under proper conditions, prove more acceptable. This and many other questions can not be determined except on the basis of just such systematic work as Mr. Burrows is doing and we are all indebted to him and to the Geological Survey for these investigations. Pending, however, much more complete studies than yet have been made, the proposed correction factors seem to the reviewer to be of academic rather than practical value.

H. Foster Bain.

Report of Proceedings of the American Mining Congress. Tenth Annual Session, Joplin, Mo., Nov. 11–16, 1907. 8vo, pp. 314. Denver, 1908.

Aside from the proceedings which include full reports of the discussion of smelter rates, prevention of fraud, amendment of the mining law and similar topics, this report includes a number of papers of technical and semi-technical character. Among the more important are: A Remedy for the Law of the Apex, by Dr. James Douglass; The History of Gold and Silver, by James W. Malcolmson; Possibilities and Limitations of Geological Survey Work as Applied to the Mining Industry, by George Otis Smith; Sliding Scale Royalty, by Louis D. Huntoon; Mining Engineering Education in the United States, by Dr. Victor C. Alderson; What Can the Profession Really Expect from the Mining School Graduate? by Milnor Roberts; Secondary Technical Education Applied to Mining, by Professor Lewis Young; Relations of the Mining School to the Mining Industry, by Professor Robert H. Richards; Some Suggestions Concerning the Training of Mining Engineers, by Robert Peele; Value of Correspondence Instruction to the Mining Man, by H. H. Stoek; How long will our Coal Supplies Meet the Increasing Demands of Commerce? by E. W. Parker; Prospecting for Oil and Gas, by Dr. Erasmus Haworth; Will the Production of Gold in the World keep pace with the Increasing Demands of Commerce and Trade, by Waldemar Lindgren; Lead and Zinc Resources of Missouri, by E. R. Buckley. The volume is of particular value to those who are interested in the relations of the mining industry to the public and to governmental activities.

H. Foster Bain.

RECENT LITERATURE ON ECONOMIC GEOLOGY.

COMPILED BY

G. F. LOUGHLIN.

METALLIFEROUS DEPOSITS.

ALUMINUM.

Les Bauxites Dans le Monde. By F. LAUR. Soc. de l'ind. min. St. Etienne. Comptes rendus. 1908. Pp. 94–104.

ANTIMONY.

Arkansas Antimony Deposits. By F. L. HESS. U. S. G. S. Bull. No. 340-D, 1908. Pp. 12.

CHROMIUM.

Les Gisements de Minerals de Fer Chromés en Grèce. By A. HABERTS. Revue Univ. des Mines. Feb., 1908. Pp. 18.

Les Gisements de Minerals de Fer Chromés en Grèce: I. Les exploitations de la Societe Hellenique des Mines. By A. HABETS. II. Notes sur les gites de minerals de fer chromés en Grèce. By N. BONANOS. Revue Univ. des Mines, et de la Met. T. XXI., No. 2, 1908. Pp. 129–148.

COBALT.

Le Cobalt Dans L'État de Jalisco (Mexico). By M. D. V. NAVARRO. Mem. y Revista de la Soc. Cientif. "Antonio Alzate." T. 25, 1907. Pp. 51–57.

COPPER.

Copper Deposits in the Western Foothills of the Sierra Nevada. By W. FORSTNER. Min. & Sci. Press. XCVI., No. 22. Pp. 743–748.

Zur Paragenesis der Kupfererze von Bor in Serbien. By F. CORNN and M. LAZEREVIČ. Zeit. f. Prakt. Geol. Jg. XVI., H. 4, 1908. Pp. 153–155.

GOLD.

Age of the Pre-Volcanic Auriferous Gravels in California. By J. S. DILLER. Proc. Wash. Acad. Sci. Vol. VIII. Feb. 13, 1907. Pp. 405, 406. (Reviewed in Jour. Geol., XVI., 4, pp. 393–394, 1908.)

The Geology and Mineral Resources of Lawlers, Sir Samuel and Darlot, Mount Ida and a Portion of the Mount Margaret Goldfield. By C. G. GIBSON. West Australian Geol. Surv. Bull. 28, 1907. Pp. 73.

Goldfield, Nevada. By T. A. RICKARD. Min. and Sci. Press. Vol. XCVI., Nos. 20–23, 1908. II., Historical. III., Geological Notes, No. 22, pp. 738–742. IV., Rich Ore and Its Moral Effects, pp. 774–777.

Gold Mining in Central Otago. New Zealand Mines Rec. XI., No. 5. Pp. 189–193. (To be continued.)

Gold Mining at Coromandel. New Zealand Mines Rec. XI., No. 5. Pp. 194–197. (To be continued.)

Gold Mining in the South. By J. F. WILKES. Proc. Eng. Assn. South. Vol. XIX., No. 1. 1908. Pp. 15.

Das Goldvorkommen bei Kasejovitz in Böhmen. By A. HOLY. Osterr. Z. f. Bg. u H. W. 1908. Pp. 165–166.

Die nutzbaren Mineralvorkomnisse inbesondere die Goldlagerstätten Deutsch Ostafrikas. By TORMAN. Monatsber. d. deutsch Geol. Ges. 1907. Pp. 60–75.

Or et cuivre de la Serbie orientale. By D. JOVANOVITCH. Paris. 1907. Pp. 225, with 1 map and drawings. Price 8.50 M.

Primary Gold in a Colorado Granite. By J. B. HASTINGS. A. I. M. E. Bi-Mo. Bull. No. 21. Pp. 311–317, 1908.

A Recent Discovery of Gold near Lake Megantic, Quebec. Abstract of report by J. A. DRESSER. Can. Min. Jl. XXIX., II. Pp. 234–235.

Report on Gold Values in the Klondike High Level Gravels. By R. G. MCCONNELL. Geol. Surv. of Canada. No. 979. Pp. 33, with colored map and illustrations.

Round Mountain, Nevada. By G. A. PACKARD. Min & Sci. Press. XCVI., No. 24. Pp. 807–809.

The Various Mining Districts of Colorado. No. 1.—The Cripple Creek District. By G. W. MILLER. Min. Sci. May 14, pp. 462–464; May 28, pp. 507–510. 1908.

Will the Production of Gold in the World Keep Pace with the Increasing Demands of Commerce and Trade? By W. LINDGREN. The Mining. Jl. Vol. LXXXIII., No. 3792. April 25, 1908.

IRON.

The Forest of Dean Iron Mine, New York. By G. C. STOLTZ. Eng. & Min. Jl. Vol. 85, No. 22. 1908. Pp. 1091–1093.

Geology of the Adirondack Magnetic Iron Ores By D. H. NEWLAND. With a report on the Mineville-Port Henry Mine Group, by J. F. KEMP. Bull. No. 423, University of the State of New York, Education Dept., April, 1908, pp. 182; illustrated 6 x 9 in.; paper. Albany, 1908, University of the State of New York.

The Iron Ores of Canada. By C. K. LEITH. Quart. Bull. Can. Min. Inst. May, 1908. Pp. 15.

Iron Ore in New Jersey. By H. B. KÜMMEL. Eng. & Min. Jl. Vol. 85, No. 24. 1908. P. 1193.

The Iron Ores of Alabama. By E. A. SMITH. Eng. & Min. Jl. Vol. 85, No. 23. 1908. Pp. 1159–1160.

A New Iron Ore Field in the Province of New Brunswick. By J. E. HARDMAN. Quart. Bull. Can. Min. Inst. May, 1908. Pp. 9.

LEAD.

From Mine to Battleship. The story of the manufacture of white lead paint. By T. A. RICKARD. Min. & Sci. Press. Vol. XCVI., No. 19. 1908. Pp. 622–636.

MANGANESE.

A Preliminary Report on the Manganese Deposits of Georgia. By T. L. WATSON. Geol. Surv. of Georgia, Bull. No. 14. Pp. 190, illustrated, 7 x 10 in.; cloth. Atlanta, Ga., 1908; The Franklin-Turner Company.

MOLYBDENUM.

Some Molybdenum Deposits of Maine, Utah, and California. By F. L. HESS. U. S. G. S. Bull. No. 340-D. 1908. Pp. 10.

PLATINUM.

Uber die Struktur des Uralischen Platins. By R. BECK. Ber. d. mathem.-phys. Klasse d. Kgl. Sächs. Ges. d. Wiss. Zu Leipzig. LIX. Pp. 389–396, with 3 plates.

RARE METALS.

Carnotite and Associated Minerals in Western Routt County, Colorado. By H. S. GALE. U. S. G. S. Bull. No. 340-D. 1908. Pp. 6.

Monazite Deposits of the Carolinas. By D. B. STERRETT. U. S. G. S. Bull. No. 340-D. 1908. Pp. 14.

SILVER.

Cobalt—Present and Future. (Editorial Correspondence.) Can. Min. Jl. Vol. XXIX., No. 10. Pp. 200–203.

TIN.

Government Prospecting for Tin in the Transvaal. By U. P. SWINBURNE. New Zealand Mines Rec. Mar. 16, 1908. Pp. 1½.

The Tin, Molybdenum and Lead Occurrences near Potgietersrust. By J. P. JOHNSTON. The Mining Jl. April 18, 1908. P. 473.

Tin Ore at Spokane, Wash. By A. J. COLLIER. U. S. G. S. Bull. No. 340-D. 1908. Pp. 11.

TUNGSTEN.

Tungsten Deposits in the Snake Range, White Pine County, Eastern Nevada. By F. B. WEEKS. U. S. G. S. Bull. No. 340-D. 1908. Pp. 3.

VANADIUM.

Occurrences of Vanadium Near Telluride, Colorado. By E. R. ZALINSKI. Eng. & Min. Jl. Vol. 85, No. 23. 1908. Pp. 1152–1153.

ZINC.

The Calamine Deposits of Southwest Missouri. By O. RUHL. The Mining World. May 16, 1908. Pp. 787–788.

NON-METALLIC DEPOSITS.

CEMENT.

Portland Cement Mortars and Their Constituent Materials. By R. L. HUMPHREY and W. JORDAN, JR. U. S. G. S. Bull. No. 331. Pp. 131, illustrated 6 x 9 in.; paper. Washington, 1908.

CLAY.

Die Thone des Hohen Westerwaldes. By F. FREISE. Zeit. f. Prakt. Geol. Jg. XVI., H. 4. 1908. Pp. 162–165.

COAL.

The Coal Industry of Montana. By J. P. ROWE. Eng. & Min. Jl. Vol. 85, No. 21. Pp. 1055–1058.

Coal Mining in Pictou County, Nova Scotia. By H. E. COLL. Eng. & Min. Jl. Vol. 85, No. 22. 1908. Pp. 1101–1103.

COAL.

Denkschrift zur Feier des Hundertjährigen Bestehens des Königlichen Steinkohlenwerks Zauckerode. By H. HURTUNG. Jahrb. f. d. Bg. u H.-W. im Kgr. Sachsen. 1906. Pp. 3–128, with 2 plates, 1 sketch and 16 figures.

COAL AND IRON.

Kohle und Eisen in Nordamerika, Reisebericht. Von Prof. BAUM. Glückauf. Jg. 44, No. 16, pp. 562–568; No. 17, pp. 593–597; No. 18, pp. 626–630; No. 19, pp. 663–667.

Über die Lagerungsverhältnisse und Verbreitung der Karbonschichten im südliche Teile des Oberschlesischen Steinkohlenbeckens. By R. MICHAEL. Zeit. des Oberschlesischen B. u. Hütt. March, 1908. 6½ pp.

Les Méthodes Paléontologiques Pour L'Étude Stratigraphique du Terrain Houiller. By A. RENIER. Revue Universelle des Mines, de la Metall, etc. T. XXI., No. 1, pp. 1–57; No. 2, pp. 149–202, 1908. (To be continued.)

Notizie sui Giacimenti di Lignite dell' Iglesiente. By B. GALDI. Rome, 1908. Pp. 56 with 6 plates. Price 1.50 M.

Le Nouveau Terrain Houiller du sud-est da la Grand-Bretagne. By E. LOZE. La Geographie. XVI. 1907. Pp. 145–163 with one text-figure.

A Report to the Bituminous Coal Trade Association on the Present and Future of the Bituminous Coal Trade. By H. S. FLEMING. Pp. 87, with 40 tables. 7 x 10 in., New York, 1908. The Bituminous Coal Trade Association.

Report of the United States Fuel-Testing Plant at St. Louis, Mo., Jan. 1, 1906, to June 30, 1907. J. A. HOLMES in charge. U. S. G. S. Bull. No. 332. Pp. 299. 6 x 9 in.; paper. Washington, D. C., 1908, Government Printing Office.

COAL AND IRON.

The Talkwa River and Vicinity, B. C. By W. W. LEACH. Geol. Surv. of Canada. Ottawa, 1907. No. 988. Pp. 27, with map.

Vorkommen und Verbreitung der Steinkohle. By F. FREISE. Stuttgart, Ferdinand Enke, 1908. Pp. 54, with 13 Figs. Price 1.60 M.

GRAPHITE.

Modes of Occurrence of Canadian Graphite. By H. P. H. BRUMELL. Quart. Bull. Can. Min. Inst. May, 1908. Pp. 15.

LIMESTONE.

Limestone in West Virginia. By G. P. GRIMSLEY. Eng. & Min. Jl. Vol. 85, No. 23. 1908. P. 1144.

OIL AND GAS.

Nouvelles Récherches et Découvertes de Naphthe dans le Caucase Occidental. By A. YERMOLOFF. Ann. d. Min. XII. 1907. Pp. 511–523.

Osservazioni Geologice Sopra i Terreni Terziari di S. Valentino (Chieto) e sopra i loro Giacimenti di Bitume. By G. B. GIATTINI. Groni di Geol. Prat. V. 1908. Pp. 169–197, with one plate.

Le Pétrole de Roumanie et le Congrès de Bucarest. By A. ARON. Ann. des Mines. T. XIII. 1908. Pp. 84.

The Waste of Mineral Fuel Resources. By I. C. WHITE. Eng. & Min. Jl. Vol. 85, No. 23. 1908. Pp. 1139–1144.

PHOSPHATES.

Phosphate Deposits in the Western United States. By F. B. WEEKS. Amer. Fertilizer, April, 1908. 3½ pp.

PRECIOUS STONES.

Neue Festellungen über das Vorkommen von Diamanten in Diabasen und Pegmatiten. By H. MERENSKY. Zeit. f. Prakt. Geol. Jg. XVI., H. 4. 1908. Pp. 155–158.

SALTS.

Das Vorkommen von Glaubersalz (Mirabilit) und Solquellen an Jenissej-Flusse in Siberien. By M. A. MOWOMEJSKY. Zeit. f. Prakt. Geol. Jg. XVI., H. 4. 1908. Pp. 159–161.

Deutchlands Kalibergbau (a review). Oest. Zeit. f. B. u H. Feb. 29, 1908. Pp. 4.

SULPHUR.

Impego del Minerale di Solfo. RASSEGNA MINERARIA. Feb. 21, 1908. Pp. 5.

TALC.

Zur Genesis der Alpinen Talklagerstätten. By K. A. REDLICH and F. CORNN. Zeit. f. Prakt. Geol. Jg. XVI., H. 4. 1908. Pp. 145–152.

WATER.

Water Resources of Beaver Valley, Utah. By W. T. LEE, U. S. G. S. Water Supply Paper. No. 217. Pp. 57; illustrated, 6x9 in.; paper. Washington, 1908, Government Printing Office.

Water Supply Investigations in Alaska, 1906–1907; Nome and Kougarok Regions, Seward Peninsula; Fairbanks District; Yukon-Tanana Region. U. S. G. S. Water Supply Paper. No. 218. Pp. 156, illustrated. 6x9 in.; paper. Washington, 1908, Government Printing Office.

GENERAL.

The Data of Geochemistry. By F. W. CLARKE. U. S. G. S. Bull. No. 320. Pp. 716, 6 x 9 in.; paper. Washington, 1908, Government Printing Office.

Origin of Pegmatite. By J. B. HASTINGS. A. I. M. E. Bi.-Mo. Bull. No. 21. 1908. Pp. 319–343.

A Theory of Ore Deposition. (Reply to H. V. Winchell's comments.) By J. E. SPURR. Min. & Sci. Press. Vol. XCVI., No. 20. 1908. Pp. 662–663. Discussion by H. W. Hixon, No. 24, pp. 800–801.

Unconformity and Ore Deposits. By OTTO RUHL. Min. & Sci. Press. Vol. XCVI., No. 23. June 6, 1908. Pp. 778–780.

Volcanic Waters. By J. B. HASTINGS. A. I. M. E. Bi.-Mo. Bull. No. 21. 1908. Pp. 345–354.

Waters, Meteoric and Magmatic. By J. F. KEMP. Min. & Sci. Press. XCVI., No. 21. 1908. Pp. 705–708.

REGIONAL.

Ubersicht uber die Nutzbaren Lagerstätten Südafrikas. By F. W. VOIT. Zeit. f. Prakt. Geol. Jg. XVI., H. 4. 1908. Pp. 137–144. (To be continued.)

Geological Survey of Canada, Summary Report for 1906. A. P. Low, Deputy Head and Director.

Die Erzlagerstätten von Pitkäranda am Ladoga-See. By O. TRÜSTEDT. Bull. No. 19, de la Commission Géologique de Finlande. Pp. 333; illustrated, 6½ x 10 in. Helsingfors, 1907, Frenckellska Tryckeri-Aktiebolaget.

Mining and Transportation in Guatemala. By C. C. SAMPLE. Eng. & Min. Jl. Vol. 85, No. 24. 1908. Pp. 1194–1195.

Ninth Annual Report of the Mining Industry of Idaho for the Year 1907. By R. N. BELL. Pp. 217; illustrated, 6 x 9 in.; paper. Boise, Idaho, 1908. Robert N. Bell, State Inspector of Mines.

The Geological Map of Illinois. By STUART WELLER. Second Edition. Bull. No. 6. Pp. 34, 6 x 9 in.; cloth. Urbana, Ill., 1907, University of Illinois.

The Geology of the Hunter River Coal Measures, New South Wales. By T. W. E. DAVID. Memoirs of the Geol. Surv. of New South Wales. Geol. No. 4, Dept. of Mines and Agriculture. Pp. 372; illustrated, 10 x 12 in.; board covers. Sydney, 1907, W. A. Gullick, Govt. Printer.

SCIENTIFIC NOTES AND NEWS[1]

THE OCTOBER MEETING of the American Institute of Mining Engineers is to be held at Birmingham, Alabama. A number of interesting papers relating especially to the economic geology of coal and iron will be presented.

PROFESSOR JUAN DE LA HUERTA, of the Department of Geology in the University of Havana, expects to visit the United States this fall.

MR. H. A. BUEHLER, State Geologist of Missouri, will devote some time this season, in company with E. O. Ulrich, of the United States Geological Survey, to a study of the older Paleozoic rocks exposed along the Mississippi.

W. H. EMMONS, of the United States Geological Survey, has been lecturing at the University of Chicago this spring.

THE CONFERENCE on the Conservation of Natural Resources, held at the White House, May 13–15, was an event of large importance in the history of this nation. The President invited the Governors of the states and territories, each of whom was asked to appoint three delegates from his state. Several eminent citizens also were invited to be present. During the conference a number of papers discussing the present condition of the nation's mineral and forestry resources were read by men thoroughly familiar with the subjects. The first paper was a discussion of the iron and coal situation, by Andrew Carnegie. Following him, Professor I. C. White, State Geologist of West Virginia, dwelt with vigor on the present wasteful methods of mining coal, and made startling statements concerning the needless waste of natural gas, which amounts to approximately 1,-

[1] Geologists, mining engineers and others interested in applied geology are invited to keep the editor informed of new investigations of mining districts or scientific studies undertaken by them, together with such other scientific and personal items as may come to their notice.

000,000,000 cubic feet every day. John Hays Hammond, representing the metal mining industries, made surprising statements concerning the relatively small amount of precious and other metals in this country yet unmined. James J. Hill, president of the Great Northern Railroad, presented a particularly strong paper on the conservation of the forests and soil, and T. C. Chamberlain, of the University of Chicago, discussed soil wastage. John Mitchell, who is thoroughly familiar with the labor question in the coal fields of the United States, discussed briefly the present wasteful methods in mining, and compared the appalling loss of life in coal mines in this country with the records of other countries. The geologists present as delegates at the Governors' conference were T. C. Chamberlain, Chicago, John Hays Hammond, New York, W. B. Clark, Maryland, H. B. Kümmel, New Jersey, Samuel Calvin, Iowa, I. C. White, West Virginia, E. H. Sellards, Florida, and George Otis Smith, Director, U. S. Geological Survey.

PROFESSOR N. M. FENNEMAN, of the Department of Geology, University of Cincinnati, sailed for Naples May 23. There he joins Professor W. M. Davis in studying physiographic problems of northern Italy and France. He will also attend the meeting of the Ninth International Geographic Congress as one of the delegates from the U. S. Geological Survey.

THE SECOND annual conference of state geologists at the invitation of the Director of the United States Geological Survey, was held in Washington May 11–12. Various phases of the work in which both the federal and State surveys are interested were discussed. Geologic nomenclature received particular attention, and valuable results were obtained by consideration of administrative methods.

FOLLOWING THE CONFERENCE, the state geologists held a meeting to discuss and take action upon the resolution passed at the meeting of the Geological Society of America, held at Albuquerque in December, for appointing a committee on geologic nomenclature. The state geologists formed a permanent organization, elected H. B. Kümmel, of New Jersey, president, and

appointed J. M. Clarke, Samuel Calvin and Eugene A. Smith as a committee to represent them on the Committee on Geologic Nomenclature. The state geologists and representatives of state surveys present at the conference were: H. Foster Bain, Urbana, Illinois; E. H. Barbour, Lincoln, Nebraska; J. A. Bownocker, Columbus, Ohio; H. A. Buehler, Rolla, Missouri; Samuel Calvin, Iowa City, Iowa; Wm. B. Clark, Baltimore, Maryland; John M. Clarke, Albany, N. Y.; A. F. Crider, Biloxi, Mississippi; G. D. Harris, Cornell University, Ithaca, N. Y.; E. Haworth, Lawrence, Kansas; R. R. Hice, Beaver, Pennsylvania; W. O. Hotchkiss, Madison, Wisconsin; H. B. Kümmel, Trenton, New Jersey; Alfred C. Lane, Lansing, Michigan; A. G. Leonard, Grand Forks, North Dakota; S. W. McCallie, Atlanta, Georgia; G. H. Perkins, Burlington, Vermont; Joseph Hyde Pratt, Chapel Hill, N. C.; A. H. Purdue, Fayetteville, Arkansas; E. H. Sellards, Tallahassee, Florida; Earle Sloan, Charleston, South Carolina; Eugene A. Smith, University, Alabama; T. L. Watson, Charlottesville, Virginia; I. C. White, Morgantown, West Virginia.

H. A. BUEHLER is the new State Geologist of Missouri, succeeding E. R. Buckley, who resigned in April to accept a position with the Federal Lead Company. Mr. Buehler was formerly assistant state geologist.

AT THE MEETING of the National Academy of Science held in Washington on April 23, among other well-known scientists elected to membership were: Professor William B. Clark, Director of the Maryland Geological Survey, Whitman Cross, Geologist, U. S. Geological Survey, and W. F. Hillebrand, Chemist, U. S. Geological Survey. S. F. Emmons, of the U. S. Geological Survey, who has been treasurer of the Academy for a number of years, was reëlected to the office.

DR. GROVE KARL GILBERT, of the U. S. Geological Survey, was awarded the Walker grand honorary prize of $1,000, at a meeting of the council of the Boston Society of Natural History held on April 15. This award is made once in five years under the terms of the will of the late William Johnson Walker "for such scientific investigation or discovery in natural his-

tory as the council may think deserving thereof; provided such investigation or discovery shall have first been made known and published in the United States of America." This prize has previously been awarded to Alexander Agassiz, Joseph Leidy, James Hall, James D. Dana, Samuel H. Scudder and Joel A. Allen.

PROFESSOR W. M. DAVIS, of Harvard University, proposes to spend June and the greater part of July in northern Italy and the Alps studying certain geographical problems. He will have with him a number of advanced students already somewhat practiced in field study and they will examine the foothills of the Apennines near Ancona; non-glaciated valleys; the basin of Florence; portions of the Mediterranean coast; changes in river courses in the headwaters of the Po; glaciated valleys of the French Alps near Grenoble, and such other points as occasion may suggest.

WILLIAM P. BLAKE, Territorial Geologist of Arizona, has been actively engaged the past winter in further investigations of the mining claims of the Salero in Tyndale district, Santa Cruz County, where the diamond drill is being used for prospecting on the lodes known as the Constitution and the Montezuma. Mr. Blake recently returned from a camping trip with Professor MacDougal, of the Carnegie Institution, into the Catalina Mountains north of Tucson at Soldiers Canyon, and into the Tortolita Mountains west of the Catalina Range. This group of mountains has rarely been visited by geologists or botanists. The foundation rocks are pre-Cambrian gneiss. There is also some quartzite, probably Cambrian. These formations are not highly mineralized with valuable ores, although promising copper deposits are found toward the north end of the range, and a gold-bearing quartz vein has been worked in the Southern Belle Canyon.

THE MARYLAND GEOLOGICAL SURVEY was granted recently by the State Legislature an appropriation of $1,000,000 for work during the coming biennial period—$50,000 for geological investigations, topographic surveying, and maintenance of the

testing laboratory; $150,000 for continuing the construction of the Baltimore-Washington road; and $800,000 for work under the State Aid Highway Law, the latter fund to be provided equally by the state and county treasuries. Roads built with this fund must be in accordance with plans and specifications and under the supervision of engineers of the Geological Survey.

A subject of widespread interest in Maryland during the session of the Legislature recently adjourned was the administration of a new fund provided by a bond issue of $5,000,000 for the construction of state highways 1,000 miles in length during the next five years. One million dollars is to be available each year for the purpose, and a fight developed over the question of whether the money should be placed in the hands of the geological survey or of a new commission. The leading newspapers of the state, business bodies of Baltimore, and farmers' organizations advocated the former disposition of the funds, knowing that in the hands of Dr. William Bullock Clark it would be effectively managed and free from political influence. The Legislature decided to appoint a new commission of six members, on which the State Geological Survey should be represented by its director, Dr. Clark, by Governor Crothers, and by President Ira Remsen, of John Hopkins University. This commission will designate the 1,000-mile system of roads which is to form main arteries through the State, and engineers of the Geological Survey will have charge of construction. Highway building was begun by the Maryland Geological Survey ten years ago, and the present munificent allotment is due to a public appreciation of the excellent results obtained by scientific construction and efficient management. The State Geological Survey is to be congratulated on being intrusted with this great public work, and on the support of the people of the state in their crusade for good roads.

THE FOLLOWING CHANGES in the instructing staff of the Massachusetts Institute of Technology have been made for the year 1908–1909: Mr. Waldemar Lindgren, of the United States Geological Survey, has been appointed lecturer in economic geo-

logy, to succeed Professor Kemp. Dr. H. W. Shimer has been appointed assistant professor of paleontology, and Mr. C. H. Clapp, instructor in geology. The majority of the members of the department are to spend the coming summer in the vicinity of Boston engaged in office and laboratory work. Professor C. H. Warren intends to do field work in Ontario, and other parts of northern Canada, and in western Massachusetts. Mr. C. H. Clapp has been assigned work by the Canadian Geological Survey in the southern part of Vancouver Island.

DR. J. C. BRANNER, PROFESSOR of geology at Stanford University, has just returned home from a year's work on the geology of Brazil. He landed at Bahia in May, 1907, with one assistant, Mr. Roderic Crandall. Work was begun in the region about Bahia with a view to ascertaining the relations of the coast sediments of Cretaceous age to the sedimentary beds of the interior. The areal distribution and general structure of these beds were worked out through northeastern Bahia and over all of the states of Sergipe and Alagoas. The coastal beds were found to extend from Bahia northward to the Rio S. Francisco above the falls of Paulo Alfonso. North of the river outliers extend in the direction of the Serra do Araripe on the Ceará frontier. For the most part these sediments rest upon granites, gneisses and schists, but in some places they rest upon folded limestones. The Rio S. Francisco cuts entirely through them, so that its channel is in the underlying rocks.

The general geology was worked out over a large area lying west of the Bahia and S. Francisco railway and southeast of the Rio S. Francisco. For the first time it has been possible to determine the sequence of the rocks in this region. Unfortunately no fossils have been found below the limestones that underlie the Cretaceous. The physical breaks and the clean-cut distinctions between certain groups made it possible however to identify these groups over wide areas, though it has not yet been possible to definitely determine their ages. The region studied embraced the greater part of the beds yielding the carbonados or black diamonds of commerce. The rocks containing the black

diamonds are pinkish quartzites and quartzitic conglomerates and sandstones and there are no eruptives of any kind associated with them except possibly at one place far removed from the principal diamond washings. The diamond-bearing rocks are supposed to be of Carboniferous age, though no fossils were found in them. They were found to cover a much larger area than was supposed. Infolded synclinal remnants and downfaulted areas extend for hundreds of miles to the north and northeast and northwest of the principal diamond mining areas, and even across the Rio S. Francisco. Some of the newly discovered areas are not workable on account of the lack of water, others are well supplied with water. For the most part the rocks of this series form a lofty mountainous region.

The great series of limestones described by earlier explorers through this portion of Brazil especially by Derby, Spix and Martius, Burton, and Wells were found to overlie the diamond bearing sediments. These limestones at many places are beautiful marbles that promise to have much importance in the future. In many places they form extensive mountains. These marbles are not utilized at present.

An older series of metamorphosed sediments forming a range of lofty mountains from southwest of Jacobina to Villa Nova and northward from the latter place is accompanied by bedded deposits of manganese ore. Owing to their distance from seaports the manganese deposits of this part of Bahia have not yet been developed. The crystalline series which probably include the oldest rocks of the region contain many pegmatite veins that carry valuable mica deposits. The only mining operations in the region are carried on by the natives in search of the black diamonds.

One of the most important results of the study of the geology of this region relates to underground waters. The region is often visited by long and serious drouths. It was found that water can be had over large areas in this region from common wells and from artesian wells.

No maps were available for the work, and there are no wagon roads in the region explored. Travel was all done on mules

and the trails were meandered and fairly good sketch maps were thus constructed of the entire area. The meandered lines were controlled by coördinates determined several years ago along the Rio S. Francisco, and on the coast. The field work occupied seven months. At the end of that time a preliminary report was prepared and delivered to Dr. Derby, the chief of the Geological Survey of Brazil, under whose direction the work was carried on. This report will be published by the minister of Public Works in English and Portuguese.

Mr. Crandall, who assisted in the field work, remains in Brazil as one of the assistants on the geological survey, and is now extending his observations to the west and north across the S. Francisco and into the adjacent states of Goyaz, Piauhy, Ceará and Pernambuco.

Mr. Branner left Rio de Janeiro, February 4, and went to the Argentine Republic. From Buenos Aires he went to Mendoza at the eastern base of the Andes to see the effects of the earthquake that destroyed that city in 1861. From Mendoza he crossed the Andes to Valparaiso and after a week at that place seeing the results of the late earthquake, took a steamer to Panama, stopping at many places on the west coast, spending a day in the nitrate fields near Iquique and three days at Lima in Peru. From Panama he went to Kingston, Jamaica, to see the effects of the earthquake at that place, and from there embarked for New York, reaching that port April 1.

THE FIELD PLANS of the Illinois Geological Survey for the present season include additional detail surveys of the coal fields carried out in coöperation with the U. S. Geological Survey, in the vicinity of Springfield, Marion, Herrin and Murphysboro. Messrs. Geo. H. Ashley and David White will spend some time in general studies. Mr. F. W. DeWolf, assisted by T. E. Savage, G. H. Cady and J. Udden, will carry on the detailed surveys and at the same time collect material for a general preliminary report on the coals of the state. Mr. E. F. Lines will study the stoneware clays of western Illinois. Dr. J. A. Udden will take up a systematic study of the deep wells of the northern

part of the state. Mr. Raymond Blatchley, with Mr. H. F. Bain, will study the oil fields. Mr. Stuart Weller will continue his stratigraphic studies of the Mississippian. Mr. Savage will devote some further time, in company with Mr. E. O. Ulrich of the U. S. Geological Survey, to the study of the older paleozoics of southwestern Illinois. Mr. J. C. Jones, under direction of Professor Salisbury, will take up the study of the Pleistocene formations of the southern part of the state. U. V. Bleminger, assisted by F. E. Layman, will study the clays of the state suitable for use in making Portland cement.

Topographic work in Illinois in 1908 will include the making of engineering maps of the Galena and Apple River sheets in the lead and zinc fields; the revision of the Hemepin and La Salle quadrangles in the northern coal fields; the completion of the Carlyle, Okawville, New Athens, West Frankfort and Herrin quadrangles in the southern coal fields; the completion of the Hardiensville map in the oil fields and preliminary work on the Baldwin and Murphysboro quadrangles. In addition, in connection with the state drainage work, level lines will be run along the Sangamon River and detailed surveys will be executed on the Kaskaskia and Big Muddy rivers.

THE KANSAS STATE GEOLOGICAL SURVEY two years ago began investigating coal mine explosions with a hope of learning something regarding their cause and possible prevention. Much valuable data was obtained, but not enough to justify publication. The work is now being taken up again and arrangements are already completed for devoting a considerable amount of time and energy to the subject in a further endeavor to accomplish something of value. It is recognized that possibly different conditions in different mines may produce different causes. In order that this work may have value therefore it should be comprehensive, and as far as possible investigations should be carried on in mines widely separated geographically and with different conditions surrounding them. The state geologist therefore would be glad to have any assistance he may receive from any parties anywhere in America or the world, and invites those

who are interested in the subject to communicate with him by mail. Letters should be addressed to Erasmus Haworth, state geologist, Lawrence, Kansas.

THE VIRGINIA LEGISLATURE has passed a bill establishing a Virginia State Geological Survey. The bureau is to have its headquarters at the University of Virginia, and the board is to be composed of the governor (ex officio), the president of the Virginia Polytechnic Institute, and two citizens. An annual appropriation of $10,000 is granted. T. L. Watson has been appointed state geologist.

PROFESSOR S. W. MCCALLIE, for a number of years senior assistant geologist of the Georgia Geological Survey, has been appointed state geologist to succeed the late W. S. Yeates. The staff of the survey now consists of S. W. McCallie, state geologist, Otto Veatch, and S. P. Jones, assistant state geologists, and Edgar Eberhart, chemist.

PROFESSOR W. H. HOBBS, of the Department of Geology, University of Michigan, will spend the coming summer in Europe. He will study the ancient volcanoes, over-thrusts and elevated shore-lines of western Scotland during the month of June; attend the Ninth International Geographic Congress, July 7 to August 6, at Geneva; and in company with Frank Leverett and Messrs. I. D. Scott and W. F. Hunt, instructors in geology and mineralogy, respectively, at the University of Michigan, will make a special study of existing glaciers in the Alps.

T. J. HOOVER, managing mining engineer and geologist for the Minerals Separation Company of London, is in this country for a few weeks on business connected with his firm. His address until July 1 will be care of Engineers Club, New York City.

A. C. VEATCH, of the U. S. Geological Survey, who was last year appointed a Special Commissioner by the President and directed to investigate the operation of the mining laws of the Australasian States—particularly those relating to coal mining—has recently returned to Washington. Mr. Veatch visited each of the Australian States and New Zealand. He found that the early history of mining law in both the United States and Aus-

tralia was in many particulars entirely parallel; that in each, leasing of mineral land was tried in the early forties, abandoned as a failure, and mineral-bearing lands sold in fee simple; that the discovery of large gold deposits, in the one region in California in 1848 and in the other in New South Wales in 1852, marks the beginning of the present mining law; that the laws then developed from the principles, which spontaneously asserted themselves in each region, that a discovery was necessary to initiate a right to minerals and that no man could hold a claim without actual development; and that the "extralateral right" doctrine found expression in each region, but that at this point the resemblance ceased.

Australia, after giving the "extralateral right" a trial for eight years, abandoned it, because it was found to lead to litigation, and this abandonment, singularly enough, occurred in the same year and month that the United States adopted it, and herein is illustrated the basic difference between American and Australian Mining Law. American mining law is to-day essentially where it was over fifty years ago, while the Australian law has been progressively improved. The Australians have, after fair trial, rejected what was bad and have produced enactments which more fully protect the rights of all concerned than those which are to-day found on American statute books.

The net result of the Australian experience is the adoption of the policy of government leasehold. Mineral lands are now, throughout Australasia, not sold but leased, and Australasian mining men are to-day practically united in the belief that mining development is better promoted by a government leasehold tenure than by freehold. In Queensland, mineral lands were freely sold until 1882; in New South Wales, until 1884, and in South Australia, until 1886, and properties held under government leasehold are to-day working side by side with those held under freehold. This conclusion of the mining men is, therefore, not a snap judgment, but is based on the result of actual trial, extending over many years. That the same general policy has been adopted in eight distinct countries, which differ greatly in political

complexion, each with an essentially independent self-governing legislature of its own, is conclusive endorsement of the unanimity of Australian sentiment in this matter and the entirely non-political character of the result.

THE UNITED STATES GEOLOGICAL SURVEY issued in May a unique map of the coal fields of the United States. Recent work of the federal geologists in the western fields has added much information concerning the extent and character of the coals and made a new map necessary. It differs from others in that it shows not only the location and extent of the coal deposits, but also by variation in color and shading, shows the character of the coal in each of the fields and whether it is at workable depth below the surface or very deeply covered by later deposits. On the margin the character and age of the coals of the different regions are described, and tables give the estimated area, original tonnage, tonnage removed, and remaining available tonnage of the fields. The remaining coal supply of the country is estimated at 2,000 billion short tons. The descriptive text and estimates were prepared by M. R. Campbell, geologist in charge of fuel resources, and the new map was compiled by R. W. Stone. It is sold for ten cents on application to the director of the survey.

D. T. DAY, Frank Leverett and N. M. Fenneman will represent the U. S. Geological Survey at the Ninth International Geographic Congress in Geneva this summer.